# CHAPTER 3
# MISSION REACH - ECOSYSTEM RESTORATION
# PLAN FORMULATION

## EXISTING CONDITION

**Mission Reach Location**. The Mission Reach lies within a portion of the SACIP extending from the Lone Star Boulevard Bridge (just downstream of the San Antonio River tunnel outlet) to approximately 3,800 feet downstream of Interstate Highway 410 in the southern part of the city of San Antonio; a distance (total river flowline) of approximately 42,300 feet (8 miles). The downstream limit of the Mission Reach corresponds to the downstream end of the transition of the SACIP floodway channel to the undisturbed San Antonio River. Figure 3-1 is a map of the Mission Reach study area. Appendix A contains aerial photographs of the Mission Reach. Appendix B contains site-specific photographs within the Mission Reach.

**Socio-Economic Characteristics**. The city of San Antonio is located within the San Antonio Metropolitan Statistical Area (MSA). The metropolitan area is a major center for tourism, government activities, and manufacturing. Population for the city of San Antonio was approximately 936,000 persons in 1992 and 1,144,600 in 2000. These figures account for more than 82 percent of the Bexar County population of 1,393,000. They also indicate an annual growth rate of about 2.2 percent.

Employment in the city of San Antonio is nearly equal in distribution among service (27 percent), and wholesale/retail (26 percent) industries. The city is a center for trucks, food products, aircraft and parts, communications, and banking. Major private employers having headquarters in San Antonio include H.E.B. Food Stores, SBC, and USAA insurance. The Bureau of Labor Statistics reports an unemployment rate of 6% for July 2003. This is identical to the national rate and slightly lower than the 6.6% unemployment rate for the state of Texas for the same time period (US Bureau of Labor Statistics, http://data.bls.gov). The median price of a home within the study area is approximately $65,000. In 2001, Bexar County had a per capita income of $21,138. For the 10 years prior, San Antonio's average annual rate of growth in per capita income grew faster than both Texas and the nation. (Sources: San Antonio Economic Development Foundation, the US Bureau of Economic Analysis, and the US Department of Commerce).

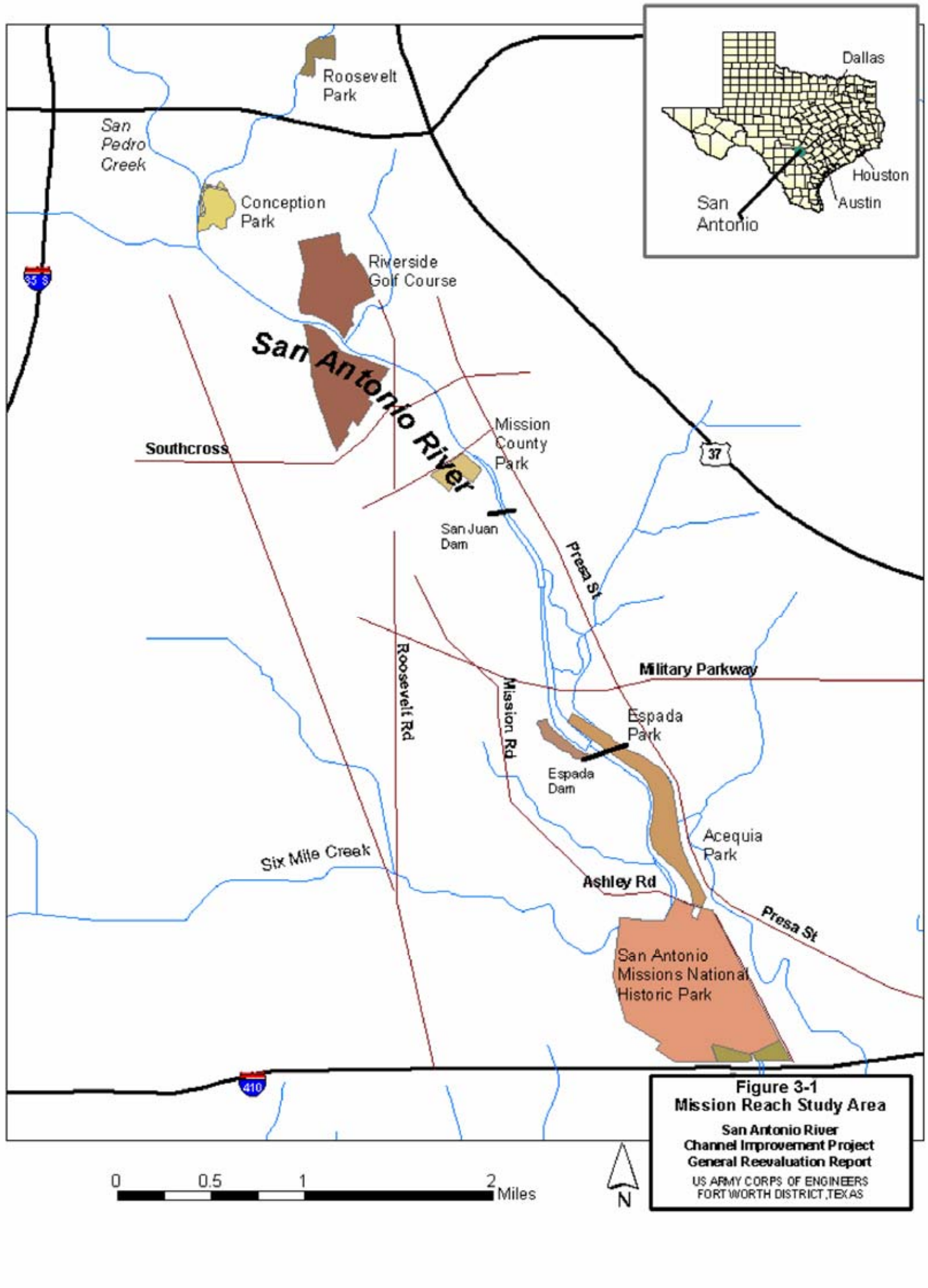
Transportation in the city is facilitated by Interstate Highway (IH) -10 running east-west, and IH-35 running north-south. These freeways provide access to the entire city of San Antonio. State Highway 281 is a north-south freeway running through downtown that provides a connection to the San Antonio International Airport.

**Physiography, Topography, Geology, and Soils**. The San Antonio Basin lies in two physiographic provinces: the Edwards Plateau and the West Gulf Coastal Plain. The Edwards Plateau occupies the portion of the basin lying generally north and west of the cities of New Braunfels and San Antonio. It was once a broad high plateau sloping gently to the east, but it is now deeply dissected by streams. It is an area of rugged hills and narrow valleys, and is sharply accentuated by the steep hills and limestone bluffs that mark the Balcones Escarpment, the dividing line between the plateau area and the coastal plains. The upper 150 miles of the Guadalupe River and its tributaries and the upper tributaries of the San Antonio River flow into steep walled valleys often 200 to 300 feet deep, which, as a rule, have very narrow strips of flat bottomland. Land elevations range from about 2,400 feet in northwest Kerr County to about 1,000 feet along the escarpment.

The West Gulf Coastal Plains extends from the Balcones Escarpment near San Antonio and New Braunfels to the coast. The escarpment is a prominent topographic feature that extends along the line of the Balcones fault zone from the Nueces River north of Uvalde eastward to San Antonio; thence, northeasterly through New Braunfels to Austin; thence, continues northeasterly a distance of 30 miles, gradually losing it's prominence. From the Balcones Escarpment, the West Gulf Coastal Plain is distinguished by rolling hills and plains in the fault zone merging into broad prairies as the Gulf Coast is approached. The larger portion of the Guadalupe-San Antonio Basin lies within this section, and the general surface elevations vary from a few feet above mean sea level at the gulf coast to about 700 feet at the base of the escarpment.

The geologic formations exposed in the Guadalupe-San Antonio Basin are Mesozoic Era in the Edwards Plateau Region and Cenozoic era in the West Gulf Coastal Plain region. They are separated by the Balcones fault extending from Del Rio to San Antonio. This fault zone resulted from subsidence of the southeastern portion of the State, in places as much as 1,000 feet at the close of the Mesozoic era. Outcrops of the Mesozoic era consist of limestone, marl, and shale. Outcrops of the Cenozoic era consist of sandstone, shale, sand and clay. Successively younger formations are encountered progressively from the Balcones fault zone to the gulf coast with lagunal, deltaic, and beach deposits near the coast. Alluvial deposits are found in the valleys of the principal rivers and their tributaries. The upland soils in the Edwards Plateau region of the Guadalupe-San Antonio Basin are shallow and stony, varying in color from light brown to black, and are friable and calcareous. The substratum is limestone and is exposed in many places. The upland soils of the West Gulf Coastal Plain region are generally deep, black or brown in color, and friable. Some soils are calcareous, and some are noncalcareous. The substratum is predominately clay or chalky marl. The soils in the region are fairly productive. The principal crops grown are oats, wheat, barley, flax, and peanuts. Practically all of the soils found in the stream valleys and subject to overflow are of alluvial origin. They are generally light brown to black in color, calcareous, and friable. The base materials are principally calcareous clay with some sandy material and gravel.

**Air Quality**. The Environmental Protection Agency uses six "criteria pollutants" as indicators of air quality, and has established for each of them a maximum concentration above which adverse effects on human health may occur. These threshold concentrations are called National Ambient Air Quality Standards (NAAQS). Areas of the country where air pollution levels persistently exceed the NAAQS may be designated as nonattainment areas. Conversely, areas of the country that do not persistently exceed the NAAQS are designated as attainment areas. The study area is located entirely within the Metropolitan San Antonio



Roosevelt Park
San Pedro Creek
Conception Park
Riverside Golf Course
San Antonio River
Southcross
Mission County Park
San Juan Dam
Presa St
37
35
Military Parkway
Roosevelt Rd
Mission Rd
Espada Park
Espada Dam
Acequia Park
Six Mile Creek
Ashley Rd
Presa St
San Antonio Missions National Historic Park
410
Dallas
Houston
Austin
San Antonio
0
0.5
1
2
Miles
N
Figure 3-1
Mission Reach Study Area
San Antonio River
Channel Improvement Project
General Reevaluation Report
US ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

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Intrastate Air Quality Control Region #217, and is currently designated as either in attainment or unclassifiable for all criteria pollutants.

**Hazardous, Toxic, and Radioactive Wastes**. A limited Phase I environmental site assessment was conducted to identify the presence or suspected presence of hazardous, toxic, and radioactive wastes (HTRW) within the study area. Initially 109 individual properties were identified for an assessment. The assessment was comprised of a “drive-by” survey, and a historical records review (title search). The Federal records review examined the U.S. Environmental Protection Agency, Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Information System, Resource Conservation and Recovery Act (RCRA) and the Emergency Notification System listings. The state records review examined the Texas Commission on Environmental Quality (TCEQ) databases for underground storage tank facilities, leaking underground storage tank facilities, and landfill closures. Records of relevant geological and hydrological information available from the U. S. Department of Agriculture, Soil Conservation Service (now the NRCS), and U. S. Geological Service were also reviewed. The assessment identified 25 properties having a “high” or “moderate” probability of containing HTRW within one mile of the study area. In the event the recommended plan is likely to disturb any of the identified sites, additional assessments and/or remedial investigations may be required. Table 3-1 displays the location of HTRW generators. The complete HTRW analysis document is located in Appendix H

**Cultural Resources**. A review of all known historic and prehistoric resources was completed for the Mission Reach study areas to identify those resources potentially impacted by the proposed project. Knowing the location of these sites provides the opportunity to avoid or minimize impacts to the sites. Within the Mission Reach study area, five prehistoric and 13 historic resources were identified. An additional 2 prehistoric sites and 20 historic sites are located within close proximity to, but outside of, the study area. The sites with prehistoric components previously recorded are identified as sites 41BX248, 41BX249, 41BX254, 41BX255 and 41BX256. Each of these sites consists of a scatter of lithic debris including projectile points and other tool fragments in many cases. The historic sites are the Electric Mill (MP-44), the Hot Wells Hotel and Bath House Site (41BX237), the dam for the San Juan acequia (41BX266), the first dam for the San José acequia (site MP-71), the Espada Dam (41BX280), the Grothaus House and Mill (41BX243 and MP-34), Texas Powder Company Mill site (MP-80), Berg’s Mill (41BX246), The Berg’s Mill Bridge (MP-27), Acequia de San José (41BX267), the San Juan Acequia (41BX268), the Espada Acequia (41BX269), and the Poor Family Cemetery (no site number has been assigned).

Portions of the study area include the San Antonio Missions National Historic Park, and is listed on the National Register of Historic Places. The San Antonio Missions National Historic Park was authorized by Public Law 95-629, November 10, 1978 for the preservation, restoration, and interpretation of the Spanish Missions of San Antonio, Texas. The park contains 819 total acres (October 2003), and received nearly 1.5 million visitors (2002). Ownership within the park boundary includes the National Park Service, the city of San Antonio, and Bexar County. In the general vicinity of the study area is Mission Conception, Mission San Jose, Mission San Juan, and Mission Espada. Within the study area are Spanish Colonel labores (agricultural fields and acequia features). Portions of the original labores are relatively unchanged, and although overgrown with vegetation and trees, Spanish Colonel land features are still evident. The NPS is currently working to restore these labores to their original condition.

Due to the presence of these resources, and the likelihood that more exist in areas not previously surveyed, buried cultural resources are likely to be disturbed during any excavation. In accordance with 36 CFR Part 800.4, prior to project construction, detailed archaeological surveys including shovel testing and backhoe testing will be completed in coordination with the National Park Service, State Historic Preservation Office, and the Advisory Council on Historic Preservation and in accordance with 36 CFR Part 800.5, detailed investigations on potential adverse impacts to the cultural landscape of the labores and other features will also be completed prior to project construction. Furthermore, archaeological monitoring during ground disturbing construction activities will be required. Appendix I contains the complete cultural and archeological analysis of the study area.

**Aquatic Resources**. Aquatic resources are comprised of all aquatic habitats and dependent species. The San Antonio River, its tributaries, numerous acequias, and river remnants provide the aquatic habitats**.** The San Antonio River consists primarily of pool/riffle/chute habitats; however, the riffles are largely created by the presence of concrete riprap rather than natural substrates. Pools exhibit a broad range in area (0.07-4.38 acres) and depth (0.28-6.46 feet) [excluding 23.74 acre Davis Lake]. Riffle areas are generally small (0.02-0.36 acre) with only 6 occurrences in the 8-mile project area. The dominant substrate within the Mission Reach of the river is coarse gravel. Silt and sand, the dominant substrate in some natural areas downstream of the floodway, were not observed by ERDC as a dominant substrate within the Mission Reach. The lack of smaller substrates within the floodway is due to the altered hydraulic condition of the river – a consequence of the SACIP construction. Acequias and river remnants provide a limited amount of refugia away from the floodway environment. They are smaller in size with vegetation to the waters edge, slower flow velocities, and improved substrates. For the most part, these are not linked to the main stem of the river.

A large number of species are dependent on aquatic habitats for their survival including macroinvertebrates, reptiles, amphibians, fishes, birds, and mammals. Macroinvertebrates make up an important component of the aquatic community as prey for fish populations. Macroinvertebrates found within the project area include mollusks in the family Lymnaeidae, mayflies, and caddisfly. Riffle areas provide important habitat for macroinvertebrate species and feeding areas for a number of fish, bird, and mammal species..

The U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC) fisheries biologists conducted surveys of fish populations within the study area in 2002 and 2003. Fish species observed include Mexican tetra (*Astyanax mexicanus),* central stoneroller *(Campostoma anomalum)*, red shiner *(Cyprinella lutrensi)*, blacktail shiner *(Cyprinellavenusta)*, common carp (C*yprinu scarpio),* golden shiner (*Notemigonus crysoleucas)*, Texas shiner *(Notropis amabilis)*, sand shiner *(N. ludibundus)*, weed shiner *(N. texanus)*, bluntnose minnow *(Pimephales notatus)*, bullhead minnow *(Pimephales vigilax)*,

**Table 3-1**
**HTRW Generator Sites – Mission Reach**

| Property Number* | Site Investigated† | HTRW Generator(s) Identified Within ⅛-mile of Property |
|---|---|---|
| 1 | Highway 90 & Stevens Avenue | Two registered RCRA "very small/large waste" generators, six registered UST sites, and four registered leaking UST sites |
| 4 | SE Military Drive | One registered RCRA "very small/large waste" generator, three registered UST sites, and one registered leaking UST site |
| 28 | City of San Antonio/CPS Mission Rd. Power Plant 303 Mission Rd. | One registered RCRA "very small/large waste" generator, one listing in the ERNS as a known reported release(s) of oil or a hazardous substance, one registered UST site, and two registered leaking UST sites |
| 29 | City of San Antonio Roosevelt Park Mission Rd. | One registered RCRA "very small/large waste" generator; one registered RCRA corrective action site; one registered RCRA facility that generates, stores, transports, treats, and/or disposes of hazardous waste; one registered UST site; and one registered leaking UST site |
| 30 | City of San Antonio I.H. 10 & Croix | One registered UST site and one registered leaking UST site |
| 37 | City of San Antonio SE Military Dr. | One registered RCRA "very small/large waste" generator, three registered UST sites, and one registered leaking UST site |
| 38 | City of San Antonio Mission Rd. | One registered RCRA "very small/large waste" generator, three registered UST sites, and one registered leaking UST site |
| 47 | San Antonio Housing Authority Riverside Dr. | One registered RCRA "very small/large waste" generator, two registered UST sites, and one registered leaking UST site |
| 48 | Lifshutz & Berlee 401 Blue Star St. | One registered UST site |
| 50 | Liberty Properties 5503 S. Presa St. | One registered RCRA "very small/large waste" generator and two registered UST sites |
| 51 | SARA | One registered RCRA "very small/large waste" generator and two registered UST sites |

| Property Number* | Site Investigated† | HTRW Generator(s) Identified Within ⅛-mile of Property |
|---|---|---|
| | 999 SW Military Pkwy. | |
| 61 | 326 Riverside Dr. | Two registered RCRA "very small/large waste" generators, two listings in the TCEQ's State Superfund Registry, six registered UST sites, and three registered leaking UST sites |
| 62 | 310 Riverside Dr. | Two registered UST sites and two registered leaking UST sites |
| 65 | 602 Riverside Dr. | One registered RCRA "very small/large waste" generator; one registered RCRA corrective action site; one registered RCRA facility that generates, stores, transports, treats, and/or disposes of hazardous waste; one registered UST site; and one registered leaking UST site |
| 69 | Martin Linen Supply Mission Rd. | One registered RCRA "very small/large waste" generator; one registered RCRA corrective action site; one registered RCRA facility that generates, stores, transports, treats, and/or disposes of hazardous waste; one listing in the ERNS as a known reported release(s) of oil or a hazardous substance; three registered UST sites; and three registered leaking UST sites |
| 70 | SAWS 515 Mission Rd. | One registered RCRA "very small/large waste" generator, five registered UST sites, and four registered leaking UST sites |
| 71 | SAWS 1603 Roosevelt Rd. | Two registered UST sites and one registered leaking UST site |
| 74 | Mission Cemetery 1700 SE Military Dr. | One registered RCRA "very small/large waste" generator, three registered UST sites, and one registered leaking UST site |
| 75 | Mission Cemetery S. Presa St. | One registered RCRA "very small/large waste" generator, three registered UST sites, and one registered leaking UST site |
| 83 | Bexar County 268 Riverside Dr. | One registered UST site and two registered leaking UST sites |
| 86 | Lifshutz & Berlee 354 Blue Star St. | Area within ⅛-mile of two registered UST sites and one registered leaking UST site |
| 88 | Bexar County 298 Riverside Dr. | One registered UST site and two registered leaking UST sites |
| 89 | Bexar County Unknown Address | Two registered RCRA "very small/large waste" generators, one listing in the TCEQ's State Superfund Registry, six registered UST sites, and two registered leaking UST sites |

Note: ERNS = Emergency Response Notification System, UST = underground storage tank; †Address provided if possible black bullhead *(Ameiurus melas)*, yellow bullhead (*Ameiurus natalis)*, channel catfish *(Ictalurus punctatus)*, Armadillo del rio *(Hypostomus* spp.), western mosquitofish *(Gambusia affinis)*, Amazon molly *(Poecilia formosa)*, sailfin molly *(Poecilia latipinna)*, guppy (*Poecilia reticulata)*, redbreast sunfish *(Lepomis auritus)*, green sunfish *(Lepomis cyanellus)*, warmouth (*Lepomis gulosus)*, bluegill *(Lepomis macrochirus)*, redspotted sunfish *(Lepomis miniatus)*, spotted bass *(Micropterus punctulatus)*, largemouth bass *(Micropterus salmoides)*, Rio Grande cichlid *(Cichlasoma cyanoguttatum)*, blue tilapia (*Tilapia aure),* Nile tilapia *(Tilapia nilotica*), red belly tilapia *(Tilapia zilli)*, and young-of-year tilapia *(Tilapia spp*.)

The surveys indicate that 25 percent of the species identified were introduced, and sixty-four percent of the native species populations were tolerant species (opportunistic – tolerant of degraded habitats). Therefore, 89 percent of the fishes surveyed within the project area are either introduced species or natives that tolerate degraded conditions. Annual surveys conducted by the SARA between 1998 and 2003 within and below the project area show that the percentage of introduced species within the SACIP is consistently 200-300 percent higher (15-57 percent introduced) than below the floodway (2-17 percent introduced).

To quantify the outputs of the existing aquatic habitat, eight aquatic habitat categories were identified by ERDC within the study area. A measure of the habitat quality and outputs for each category were calculated using a habitat suitability index (HSI) and habitat units (HU). (A detailed discussion of the methodology for developing HSI and HU values is presented beginning on page 3-51). The acreages of each habitat category and the HUs they provide under the existing condition are shown in Table 3-2. The 69.23 acres of aquatic habitat currently available only provide 26.97 HUs. This means that under existing conditions, the aquatic habitat is only performing at approximately 39-percent of its maximum capacity. Also of note is that for several categories (tributary mouths, embayments, etc.) there are a limited number available in the eight-mile study area, and while there are river remnants outside the flood control channel, most are not connected to the main San Antonio River channel.

**Table 3-2**
**Aquatic Habitat Existing Conditions**

| Habitat Category | Number in project area | Existing Conditions Acres | Existing Conditions HUs |
|---|---|---|---|
| Pool | 20 | 39.37 | 15.72 |
| Chute | 21 | 19.34 | 9.40 |
| Riffle | 6 | 1.26 | 0.99 |
| Chute below pool | 8 | 0.37 | 0.20 |
| Scour Pool | 1 | 1.25 | 0.55 |
| Embayment | 1 | 0.01 | 0.01 |
| Tributary Mouth | 1 | 0.17 | 0.10 |
| River Remnant | 0 | 0.00 | 0.00 |
| Dry Channel | 1 | 7.46 | 0.00 |
| **Total** | **59** | **69.23** | **26.97** |

*Habitat categories are defined beginning on page 3-53.

**Water Quality**. The Texas Commission on Environmental Quality (TCEQ) has divided the San Antonio River basin into 13 classified segments. The study area falls within segment 1911 with designated uses of aquatic life, contact recreation, general, and fish consumption. Both Park and Mission reaches do not support the contact recreation use due to bacterial contamination. Analyses of recent water quality data indicated ammonia nitrogen, orthophosphorous and total phosphorous have met state screening criteria and were identified as no concern. Additionally temperature, pH, dissolved oxygen, chloride, sulfate, and total dissolved solids were fully compliant with state stream standards.

Water quality has steadily improved since 1985. Since then, the Rilling Road Waste Water Treatment Plant discharge to the San Antonio River has been eliminated and a new larger capacity state of the art treatment facility is in operation and discharging to the Medina River. Since 1987, advanced waste treatment has been instituted at the three major City of San Antonio wastewater treatment plants. The City of San Antonio has also upgraded and improved maintenance on the sewage collection systems reducing overflows and leakage. As a result, dissolved oxygen concentrations in the San Antonio River have increased substantially and have been maintained above the State of Texas stream standard of 5.0 mg/L.
As water quality in the San Antonio River has improved (better waste water treatment) SARA biologists have observed an increase in the number of pollution intolerant fish species in the San Antonio River near the confluence with the Medina River, an indication that water quality has improved (San Antonio Water System 2004). There are no water quality issues within the Mission Reach of the San Antonio River that would affect aquatic life use.

In 1991, the Texas Legislature passed the Texas Clean Rivers Act [Senate Bill 818]. The Act was intended to move Texas towards comprehensive water resources planning and management to ensure the integrity of the state's water supply over the long term. The Clean Rivers Act requires an ongoing assessment of water quality issues and management strategies statewide. The Act established the Texas Clean Rivers Program under the Texas Water Commission (now the Texas Commission on Environmental Quality [TCEQ]). Under the Texas Clean Rivers Act, SARA is responsible for:

- Studies to determine criteria and standards for water quality.
- Development and operation of wastewater disposal systems.
- Water quality monitoring, data collection, analysis and basin-wide water quality planning.
- Coordination of water quality activities.
- Review, evaluation, and comment on permit applications.
- Achieving public support for water quality programs and regulations.
- Development and operation of regional solid waste disposal facilities where needed.
- Cooperation in enforcement of water quality regulations.

Water quality monitoring within the study area is provided through several different programs administered by the Environmental Services Department of SARA. SARA biologists and field staff collect water quality samples, flows, and field parameters.

Additionally, they assess aquatic insect and fish communities, and perform habitat assessments to evaluate the health of the rivers and creeks within the basin.

SARA samples field parameters twice per month at 14 fixed station sites along the San Antonio River from the headwaters area downstream to Goliad, Texas. These samples are analyzed for total suspended solids, fecal coliform, nitrogen (NH3, NO2, NO3), phosphorous (TPO4 and OPO4), and Escherichia coli. At the time of sampling, observation of ambient conditions are documented, stream cross sections and flows are measured, and water quality field parameters (dissolved oxygen, temperature, specific conductance, total dissolved solids, pH and Secchi depth (clarity)) are recorded. In addition, 24-hour diel measurements of water quality field parameters are conducted utilizing multi parameter data sondes at each fixed station site at least once per year. All monitoring procedures and methods follow the guidelines dictated in the TCEQ *Surface Water Quality Monitoring Procedures Manual* (GI-252).

The SARA Environmental Services Division conducts monitoring of storm event discharges in order to assist in characterizing the quality of storm water discharges from the Municipal Separate Storm Sewer System. Monitoring is performed at Ingram Road on Leon Creek tributary during representative storm event discharges. Analyses conducted include biochemical oxygen demand, chemical oxygen demand, oil and grease, total suspended solids, total dissolved solids, total nitrogen, total Kjeldahl nitrogen, total nitrate, total ammonia, total phosphorus, dissolved phosphorus, total cadmium, total chromium, total copper, total cyanide, total lead, total nickel, total zinc, fecal coliform, Enterococci, pH, hardness, temperature, and diazinon.

**Riparian Resources**. The study area lies on the edge of four major vegetational areas: Edwards Plateau, Blackland Prairie, Post Oak Savannah, and South Texas Plains. Native vegetation has been adversely impacted by the construction of the SACIP, urban development, livestock grazing, and farming. Some remnants of the original bottomland forest can be found along the San Antonio River corridor, mostly in the form of large native specimen trees such as live oak, pecan, sycamore, cypress, American elm, mesquite, and Arizona ash.

With rare exception, there are no trees or shrubs within the channel. Due to the mowing regime and the riprap lining of the channel, no semblance of a functioning riparian zone exists for the entire length of the Mission Reach. The vegetational community along the slopes of the flood control channel can be characterized as non-native short grass meadow dominated by Bermuda grass (*Cynodon dactylon)*. Other species occurring in this community type include Johnsongrass (*Sorghum halepense)*, bastard cabbage (*Rapistrum crantz)*, prairie verbena (*Verbena bipinnatifida)*, gaillardia (*Gaillardia aristata)*, Queen Anne's lace (*Daucus carota)*, and purple three-awn (*Aristida purpure)*. On the flatter areas adjacent to the river, the vegetational community can be characterized as a non-native tall grass meadow. These areas are dominated by Johnsongrass. Other species present include Bermuda grass, rescue grass (*Bromus unioloides)*, three-awn, King ranch bluestem (B*othriochloa ischaemum)*, giant reed (*Arundo donax)*, and elephant's ear (*Xanthosoma schott)*. One exception to the Johnsongrass dominated community occurs in areas along the river where the soil is highly disturbed. In these areas, giant ragweed (*Ambrosia artemisiifolia)* is the dominant species.

Vegetational communities adjacent to the flood control channel include one of the two-grass meadow communities described above or one of four other vegetational communities. These communities include *parkland*, *legume thicket woodland*, *mid-successional woodland*, or *late-successional woodland*. *Parkland* exists in areas where mown Bermuda grass and rescue grass dominate the under story with pecan (*Carya illinoinensis)*, cottonwood (*Populus deltoids)*, hackberry, and/or Chinaberry as the over story components. The trees are generally widely spaced with large areas of mown-grass meadow between. *Legume thicket woodlands* are dominated by mesquite (*Prosopis glandulosa*) and huisache (*Acacia smallii)*. Other early successional species such as hackberry (*Celtis occidentalis)* and Chinaberry (*Melia zedarach)* are also often a component of the woody overstory in these communities. This type of community has an open canopy, allowing for a dense under story, which typically is dominated by invasive grasses such as rescue grass, Bermuda grass and Johnsongrass. Texas winter grass (*Nasella leucotricha)*, a native species, is also present within these areas. *Late successional woodlands* represent a community with the highest diversity of woody native species. Pecan, hackberry, mulberry (*Morus* sp.), cottonwood, and bald cypress (*Taxodium distichum)* are included in the over story component of this community type. Johnsongrass and beggar's tick (*Torilis arvensis)* are the dominant understory species of this community. *Mid-successional woodlands* are the most common woodland community occurring along the overbanks of the San Antonio River. The primary native overstory species in this community are pecan and hackberry, and the most dominant non-native species is Chinaberry. Younger woodlands generally have a higher density of Chinaberry than the older versions of this community type. Additionally, younger mid-successional communities may include varying densities of condalia (*Condalia* sp.), mesquite, and retama (*Parkinsonia aculeate)*. Common understory species are rescue grass, Bermuda grass, privet (*Ligustrum* spp.) and mustang grape (*Vitis candicans)*.

Vegetation was assessed by the Lady Bird Johnson Wildflower Center and the USFWS within the study area. Six vegetational categories were identified. USFWS determined the habitat outputs of these categories using a habitat suitability index (HSI) and habitat units (HU). (A detailed discussion of the methodology for developing HSI and HU values is presented beginning on page 3-51). The acreages of each habitat category and the HUs they provide under the existing condition are shown in Table 3-3. The 308.84 acres of grassland within the channel provides no outputs (HU = 0.0) as riparian habitat. The remaining 85.37 acres of woodlands occur outside the floodway. These woodlands are providing 31.38 HUs, which is 37% of their maximum capacity.

**Table 3-3**
**Riparian Habitat Existing Conditions**

| Vegetation Category | Existing Condition Acres | Existing Conditions HUs |
|---|---|---|
| Non-native grassland | 308.84 | 0.00 |
| Legume woodland | 46.95 | 17.37 |
| Late successional woodland | 0.02 | 0.02 |
| Mid successional woodland | 0.91 | 0.44 |
| Park woodland | 10.65 | 3.62 |
| Woodland | 26.84 | 9.93 |
| **Total** | **394.21** | **31.38** |

Historically, the study area supported a diverse native wildlife community. However, due to human development and the destruction of habitat, preferred habitat for riparian and water dependent species no longer exists. Small mammals present in the area include: armadillo (*Dasypus novemcinctus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis virginiana*), cottontail (*Sylvilagus audubonii*), fox squirrel (*Sciurus carolinensis*), Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*), Mexican ground squirrel (*Spermophilus mexicanus*), and cotton rat (*Sigmodon* spp.). In most cases, these mammals are limited to park areas. Leopard frogs (*Rana pipiens*) and cricket frogs (*Acris crepitans*) are abundant. Gulf coast toad (*Bufo valliceps*), red-eared slider (*Trachemys scripta elegans*), yellow mud turtle (*Kinosternon flavescens flavescens*), green anole (*Anolis carolinensis*), diamondback water snake (*Nerodia rhombifer*), blotched water snake (*Nerodia erythrogaster transversa*), checkered garter snake (*Thamnophis marcianus*), Mediterranean gecko (*Hemidactylus turcicus),* and soft shell turtle (*Apolone spinefera*) are also present.

There are close to 400 species of birds, both migrant and resident, found in Bexar County. Species observed during site visits include double crested cormorant (*Phalacrocorax auritus),* great blue heron (*Ardea herodias),* little blue heron (*Egretta caerulea*), great egret (*Casmerodius albus), s*nowy egret (*Egretta thula),* mallard (*Anas platyrhynchos),* black-bellied whistling duck (*Dendrocygna bicolor),* killdeer (*Charadrius vociferous),* turkey vulture (*Cathartes aura),* crested caracara (*Polyborus plancus),* red-tailed hawk (*Buteo jamaicensis),* coopers hawk (*Accipiter cooperii),* mourning dove (*Zenaida macroura),* rock dove *(Columba livia),* belted-kingfisher (*Ceryle alcyon*), scissor-tailed flycatcher (*Tyrannus forficatus),* blue jay (*Cyanocitta cristata),* American crow (*Corvus brachyrhynchos),* tufted titmouse (*Parus bicolor),* Carolina chickadee (*Parus carolinensis),* Northern mockingbird (*Mimus polyglottos),* white-eyed vireo (*Vireo griseus),* yellow-rumped warbler (*Dendroica coronata),* house sparrow (*Passer domesticus),* black-chinned hummingbird (*Archilichus alexandri),* Northern cardinal (*Cardinalis cardinalis),* red–winged blackbird (*Agelaius Phoeniceus),* and Great tail grackle (*Quiscalus mexicanus).*

**Threatened and Endangered Species**. Texas lists 195 species as being threatened or endangered within the state, including 63 mammal, 37 amphibian or reptile, 35 bird, 20 fish, 2 invertebrates, and 28 plant species. There are 11 species listed by the USFWS as endangered in Bexar County. They are black-capped Vireo (*Vireo atricapilla*), golden-cheeked warbler (*Dendroica chrysoparia*), braken bat cave meshweaver (*Cicurina venii*), Cokendolpher cave harvestman (*Texella cokendolpheri*), Government Canyon bat cave meshweaver (*Cicurina vespera*), Government Canyon bat cave spider (*Neoleptoneta microps*), Helotes mold beetle (*Batrisodes venyivi*), Madla's cave meshweaver (*Cicurina madla*), robber baron cave meshweaver (*Circurina baronia*), and two unnamed ground beetles (*Rhadine infernalis* and *Rhadine exilis*). Cagles map turtle (*Graptemys caglei*) and the black-tailed prairie dog (*Cynomys ludovicianus*) are listed as Candidate species. Eight of the Federal listed species are found only in caves within the Texas Hill Country.

*Black-capped vireos* [federal/state listed as endangered] nest in Texas during April through July, and spend the winter on the western coast of Mexico. Nests are usually built in shrubs such as shin oak or sumac. Habitat is comprised of rangeland with scattered clumps of shrubs separated by open grassland. They are endangered because of clearing or overgrazing, less frequent range fires, and brown-headed cowbird parasitism. According to the USFWS, there is no designated critical habitat for back-capped vireo in the study area.

*Golden-cheeked warblers* [federal/state listed as endangered] nest only in central Texas mixed Ashe-juniper and oak woodlands in ravines and canyons. Warblers eat insects and spiders found on the leaves and bark of oaks and other trees. Habitat for the golden-cheeked warbler is woodlands with tall Ashe juniper (colloquially "cedar"), oaks, and other hardwood trees. Golden-cheeked Warblers are endangered due to clearing of woodlands for urban development, or reservoir construction. According to the USFWS, there is no designated critical habitat for golden-checked warblers in the study area.

*Cagle's map turtle* [federal candidate for listing, state listed as threatened] occurs in scattered sites in seven counties in Texas on the Guadalupe, San Marcos, and Blanco Rivers. The turtle has been extirpated from the San Antonio River Basin. Loss and degradation of riverine habitat from large and/or small impoundments (dams or reservoirs) is the primary threat to Cagle's map turtle. One detrimental effect of impoundment is the loss of riffle and riffle/pool transition areas used by males for foraging. Depending on its size, a dam itself may be a partial or complete barrier to Cagle's map turtle movements and could fragment a population. Construction of smaller impoundments and human activities on the river has likely eliminated or reduced foraging and basking habitats. Cagle's map turtle is also vulnerable to over collecting and target shooting.

*Black-tailed prairie dogs* [federal candidate for listing] have a wide distribution throughout western North America, including portions of Canada, the United States, and Mexico. Although still present throughout much of it's historic range, the population of black-tailed prairie dogs has declined by 99 percent. Reductions in occupied habitat and habitat loss/degradation are related to the conversion of prairie grasslands to farmland, urban development, extensive poisoning efforts, unregulated shooting, disease, combinations of these factors, and other causes. According to the USFWS, there is no designated critical habitat for black-tailed prairie dogs in the study area.

**Wetlands**. There are no jurisdictional wetlands identified within the study area.

## PROBLEM IDENTIFICATION

Historically, the San Antonio River was wider and shallower, with naturally occurring variation of side slopes and a sediment supply in balance with a fully functional floodplain. The river was more sinuous than it is today, with flooding over a much wider floodplain (average of 5 times wider), providing a higher width/depth ratio. The SACIP straightened the river, increased its gradient, confined flood flows to a relatively narrow floodway, increased velocities, and allowed urbanization to encroach upon the river's historic floodplain. Intrinsic riverine functions and values have been sacrificed for the purpose of confining and conveying flood flows more rapidly downstream. The heavily urbanized basin creates a rapid runoff response in a region that is known for intense storms. Basin hydrology is characterized as a bimodal, flashy ephemeral system superimposed on a spring-fed base flow condition. Channel incision and reduced sediment supply are observed throughout the Mission Reach.

Significant components of fish and wildlife habitat were lost due to the construction and maintenance of the SACIP. A review of historical aerial photos taken prior to channelization reveal a wide meandering river with frequent bendway pools, riffles, and point bars. Trees grew to the water's edge where undercut banks and root wads provided vital habitat for the native fishes of the river. The tributaries associated with the river created unique habitats where they joined with the main stem of the river, and provided important spawning habitat for certain species which live in the main stem of the river as adults. The floodplain of the river contained numerous shallow, heavily vegetated floodplain depressions and pools. These seasonally aquatic habitats served as nursery areas for amphibians and flood-adapted fishes native to the river. The riparian corridor provided habitat to native wildlife by providing vegettional diversity that is available only in the riparian areas in this region of Texas. The resulting habitat losses associated with the channelization of this river contributed to alarming trends for wildlife and habitat both at the local, state, and national level.

**Degradation of the SACIP and Sediment Transport.** The watershed's transformation to an urban character appears to have had a typical effect on sediment supply conditions where sediment is released by construction activity as the watershed becomes developed and then supply is reduced as a built out condition is approached. Channel conditions reflect the basin's urbanized hydrologic response and sediment supply characteristics. Channel incision (vertical erosion) and reduced sediment supply are observed throughout the river despite concerted channel armoring efforts. The complete analysis is located in Appendix C.2 - Geomorphic and Sediment Transport Technical Memorandum (GSTTM).

**Historic Channel Assessment**. A channel assessment was performed to understand the physical processes affecting the river system and to evaluate the river's response to future construction efforts. A comparison of previous to existing conditions was carried out to assess the tendency for future adjustments in channel plan form, slope, and cross section geometry. Moreover the analysis provides information to support the sediment transport analysis and design of channel stabilization measures.

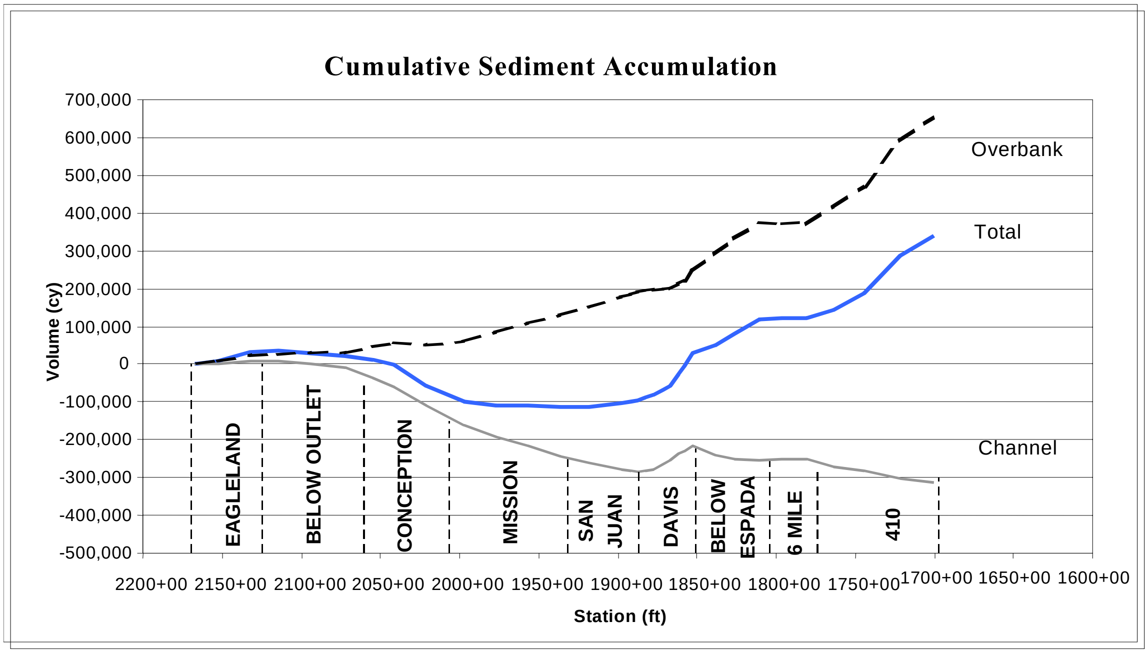
A *comparison of channel alignments* was performed to determine the amount of induced plan form change and to assess how it has affected channel stability. Most of the plan form change resulted from human induced flood reduction efforts conducted after the flood of 1913. The construction of the SACIP severely altered the channel plan form by straightening over 12 continuous miles of river. Much of the historical plan form data was generated from the channel alignment represented in the as-built plans, and was used to calculate historic and existing channel sinuosity values.

Sinuosity is computed as the channel length divided by the valley length or channel slope divided by valley slope and measures of the amount of meandering in a river system. The historical plan form resulted in an average sinuosity of approximately 1.7 for the Mission Reach, while the current channel has an average sinuosity of 1.0. Significant incision of the pilot channel has been observed in some areas, while Espada Dam and the San Juan Diversion structure have limited incision.

Another method to quantify the extent of historic change in channel plan form is the measurement of the mean radius of curvature from the historic (pre-1957) channel plan form. The radius of curvature is defined as the linear distance between the center of the bend and the center of the channel. The mean radius of curvature was measured at representative meander bends from the historic channel plan form of the San Antonio River. The radius of curvature of the same floodway segments was measured from the existing channel alignment where applicable. The existing channel plan form mean radius of curvature has significantly increased from its historic condition as a result of urbanization and flood control projects. Specific impacts include meander cutoffs and channel straightening, channelization, channel maintenance and sediment removal, channel and floodplain encroachment, vertical grade control, and lateral confinement with concrete and riprap. Many existing project reach segments have no measurable bend radii based on a straightened channel planform while other channel segments are passively meandering, meaning the existing meander bends are locked in place and limited by the existing floodway alignment and immobile lateral channel boundaries of the pilot channel.

*Comparisons of channel cross sections* were also undertaken to investigate the amount and distribution of sediment stored or eroded from the in the San Antonio River since construction of the floodway. This information was used to assess erosion and deposition patterns throughout the project sub-reaches. Sediment accumulation values were computed from the change in cross sectional area multiplied by distance along the south reach corridor. The comparative cross sections were subdivided into channel and over bank areas and the difference in section areas were computed. A total of 33 cross sections were selected at intervals representative of all reach conditions. The cumulative sediment accumulation since construction of the San Antonio River floodway is represented in Figure 3-2**.** A positive slope indicates sediment accumulation, and a negative slope indicates sediment erosion. This analysis revealed a general loss of material (erosion) in the main channel and deposition in the over bank areas.

**Figure 3-2**
**Historical Sediment Accumulation in the San Antonio River**
**(As-Built to Existing Condition)**




*Channel Profile Analysis* involved comparison of channel and over bank profiles to evaluate the degradation or aggradation trends in the study area and compute corresponding slopes. Data from the comparative cross section analysis were used to develop the existing and as-built profiles and channel slopes. Additionally information contained in the as-built plans was used to develop the historic channel profile (pre-1957). The channel profiles were then used to calculate the change in slope that has occurred over the last several decades. Using the channel profiles, channel bed slopes were computed. The analysis revealed there is erosion potential in the area below the San Antonio River tunnel outlet, becoming more significant toward Espada Dam. The transition area to a more depositional environment occurs further downstream due to the influence of the San Juan Diversion structure and Espada Dam. Channel incision and significant aggradation in the over banks was identified below Espada and IH-410.

*Specific Gage Analysis* was performed using information from the San Antonio River at the Loop 410 gage (# USGS 08178565) with low-flow measurements obtained from 1987 to 2002 published by the USGS at this site. A running 5-year average of low flow measurements were used to develop a stage versus discharge relationship for the period of record at this gage. Groups of measurements representing each base year included the two years prior and two years following the base year. The group of measurements was used to develop a regression line relating stage as a function of discharge for each base year. The regression equations were used to compute the stage for a specific discharge selected for the analysis. A discharge of 100 cfs was selected and the corresponding stage for each base year was computed. The results indicate a downward trend in stage over the period of record.

The decrease in stage is approximately 1 foot over the 14-year period. This corresponds with the amount of degradation observed in the main channel throughout the 410 sub-reach. The main channel of the 410 reach has experienced on average about 4 feet of degradation in the last 30 years, which could equate to more than 1 foot every 10 years. The specific gage analysis suggests that that the trend has continued to occur over the recent 10-year period and could likely be expected into the future.

The without project *hydrologic and hydraulic models* were developed for the San Antonio River using a Federal Emergency Management Agency (FEMA) Limited Map Maintenance Program (LMMP) Study. The LMMP Study consisted of the development of new San Antonio River and San Pedro Creek basin hydrology models using the HEC-1 Flood Hydrograph Package and new San Antonio River and San Pedro Creek hydraulic models using the Hydraulic Engineering Center River Analysis System River Analysis System (HEC-RAS). The modeling process incorporated the best available topographic, bridge, and channel data and the San Antonio River Tunnel (SART) and San Pedro Creek Tunnel capacity rating curves. SART physical model data, developed by the St. Anthony Falls Laboratory at the University of Minnesota in November 2001, was incorporated into the HEC-1 and HEC-RAS models. The HEC-RAS model consists of eight plans representing the following flood events: 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 250-year, and 500-year. The complete hydrologic and hydraulic analysis is located in Appendix C.1.

**Historic Aquatic and Riparian Habitats**. The riverine habitat throughout the Mission Reach was characterized by a broadly meandering, spring-fed stream occupying a much larger floodplain area than it does today. Pools, riffles, and chutes were the predominant microhabitat types with deep pools occurring at river bends and sand or gravel point bars forming at frequent intervals. The water was cooled by the adjacent overhanging vegetation during warm months and warmed by sunlight during cold months after deciduous vegetation became dormant. The riparian corridor once supported a diverse population of native plants including large trees; pecan, black walnut (*Juglans nigra)*, oak (*Quercus* spp.), cypress, black willow (*Salix nigra)*, hackberry, sycamore (*Platanus occidentalis)*, elm (*Ulmus* spp), and Arizona ash (*Fraxinus texensis)*; shrubs (button bush (*Cephalanthus occidentalis)*, , possum haw (*Viburnum nudum)*, lantana (*Lantana camara)*, hop tree, sumac (*Rhus* spp.), dewberry (*Rubus* spp.), yaupon (*Ilex vomitoria)*,  viburnum), and many species of vines and forbs. Faunal species supported by this habitat included multiple species of mammals, reptiles, and amphibians.

## PROBLEM AND OPPORTUNITY STATEMENTS

Construction and operation of the Mission Reach portion of the SACIP have adversely impacted the aquatic and riparian habitat within and adjacent to the San Antonio River. Photographs 3-1 through 3-7 illustrate the level of degradation that has occurred. The degradation is defined by the physical characteristics, lack of diversity, sustainability, and variation in physical structure in both the aquatic and riparian communities illustrated by the following:

**Photograph 3-1**
**Modified and Natural Configuration of the San Antonio River**

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**Photograph 3-2**
**Typical Existing Grade Control Structure with Outfall Structure**

**Photograph 3-3**
**Existing Habitat Within the Mission Reach**

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**Photograph 3-4**
**Existing Habitat Within Mission Reach**

**Photograph 3-5**
**Existing Habitat Within Mission Reach**

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**Photograph 3-6**
**Existing Habitat Within Mission Reach**

**Photograph 3-7**
**Existing Habitat Within Mission Reach**

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- Severely altered hydrologic regime leading to the loss of natural riverine function with respect to slope gradient, sinuosity, and sediment transport;
- Severely altered hydrologic regime resulting in high velocities, erosion and bank-failure, incision of channel bottom, and undesirable sedimentation; and
- Severely altered hydrologic regime causing the loss or degradation of natural river and flood plain structures including pool, riffle, and chute sequences, vegetated channel, shorelines, wetlands, and oxbows; and consequently -
  - A lack of food, shelter, and breeding habitat for aquatic species.
  - A lack of diversity in water depths.
  - A lack of diversity in water velocities.
  - A lack of diversity in water surface areas.
  - A lack of diversity in river substrate.
  - A lack of littoral zones and slack-water areas.
  - Lack of aquatic vegetation.
  - The proliferation of non-native, invasive vegetation.
  - The proliferation of non-native, invasive fish species and the subsequent decline of native fish species.
  - Lack of food, shelter, and nesting habitat for resident and migratory waterfowl and wading bird species.

- The destruction of native riparian vegetation, and as a result:
  - A lack of vegetation at waters edge.
  - A lack of vegetative cover over the water and shade to mitigate water temperatures.
  - The loss of allochthonous material (originated from outside) to aquatic habitats.
  - A lack of over bank aquatic species habitats.
  - A lack of food, shelter, and nesting habitat for riparian bird species.
  - A lack of food, shelter, and breeding habitat for riparian wildlife.
  - A proliferation on non-native, invasive vegetation.
  - A lack of connectivity between riparian and aquatic habitats.
  - A lack of connectivity between upland and aquatic habitats.
  - A lack of connectivity between upland and riparian habitats.

## PLANNING OBJECTIVES

The San Antonio River and riparian corridor lack the necessary basic components to provide habitat diversity under its existing and expected future condition. The Mission Reach of the river has become an impediment to indigenous aquatic and riparian wildlife species. Although the river can never be restored to pre-SACIP condition, the functions and values associated with a more naturally performing ecosystem can be greatly improved. Further, reconnection to existing habitats on either side of the river would result in benefits to a much larger area. Planning objectives are the desired changes between the without- and with-project conditions. In order to identify appropriate restoration measures, the following planning goals and objectives have been established.

**Planning Goal # 1**: Restore a diverse and sustainable ecosystem along the San Antonio River by improving the quality and/or increasing the quantity of riparian and aquatic habitat. The following restoration objectives were established to achieve this goal:

- Restore, to the maximum extent practicable, a more natural, sustainable, riverine function with respect to slope gradient, sinuosity, and sediment transport.
- Restore the quality and quantity of pool, riffle, and chute sequences.
- Restore oxbows.
- Restore wetlands.
- Restore aquatic and riparian vegetation and vegetation at water's edge.
- Restore the connectivity between upland, riparian, and aquatic habitats.
- Restore food, shelter, and breeding habitat for aquatic species.
- Restore food, shelter and nesting habitat for waterfowl and wading bird species.
- Restore food, shelter, and breeding habitat for riparian wildlife.
- Improve diversity in water depth.
- Improve diversity in water velocity.
- Improve diversity in water surface areas.
- Improve diversity in river substrate.
- Provide littoral and slack water areas.
- Increase the proportion of native fish to non-native fish.

**Planning Goal #2:** Provide for compatible recreational features and other quality-of-life enhancements to benefit the citizens of San Antonio, the region, and the nation.

**Planning Constraints**. Planning constraints are project consequences to avoid. Constraints are designed to avoid undesirable changes between the without- and with-project conditions and have the effect of limiting choices. In order to identify appropriate restoration measures, the following planning constraints have been established.

- The establishment of a more natural riverine function and any restoration measure will not increase the existing 100-year water surface elevation.
- The establishment of a more natural riverine function and any restoration measure will not impact existing water rights.
- The establishment of a more natural riverine function and any restoration measure will avoid, where possible, disturbing any adjacent high quality ecological resources.
- The establishment of a more natural riverine function and any restoration measure will avoid, where possible, disturbing known or suspected significant cultural resources including culturally significant land forms.
- The establishment of a more natural riverine function and any restoration measure will avoid, where possible, disturbing known or suspected hazardous material or contaminant.
- The establishment of a more natural riverine function and any restoration measure will avoid, where possible, long-term adverse impacts to air and water quality, as well as minimize noise pollution.
- The establishment of a more natural riverine function and any restoration measure will minimize real estate acquisition.

## RESTORATION MEASURES CONSIDERED

The potential ecosystem restoration measures are comprised of three separate but dependent components. The first is restoration of the floodway channel to a more natural condition by decreasing slope gradients and velocities, balancing sediment transport, and increasing conveyance. The second component, restoration of riparian vegetation, will be incorporated. Finally, a suite of special aquatic measures will diversify the types of high output, quality aquatic habitats within the study area.

**No Action.** This is the without-project condition. Under this condition there would be no changes to the existing condition of the Mission Reach for ecosystem restoration purposes.

**Channel Modifications**. The current floodway was designed, constructed, and maintained as a grass-lined channel. The ability to restore riparian vegetation to the floodway without violating the constraint of not increasing the 100-year water surface elevation can be accomplished by increasing the conveyance of the channel. Restoring a more balanced sediment transport function would be accomplished through the creation of a pilot- and base flow channel based on the principles of fluvial geomorphology. The removal of material from the floodway associated with the pilot-and base flow channel provides the additional conveyance allowing vegetation to be placed within the floodway.

Channel modifications would increase channel sinuosity, reduce channel slope, and velocities thereby improving sediment transport, i.e., allow for a more diverse channel substrate. Channel modifications would improve also aquatic habitat quantity and quality by increasing water depth, decreasing turbulence, reducing water temperatures in the summer, and increasing cross-sectional diversity in microhabitat. This would provide fishes with refugia from shoreline stranding, shear-related stress, hyperthermia, and bird predation that typically occur during extreme low water. Lower velocities at inside bendways would result in deposition of suspended solids and the creation of point bars, increasing cross-sectional variation in depth and water velocity.

**Pool, Riffle, Chute (Run) Sequences**. Pool, riffle, and run sequences have been and are natural features of the San Antonio River, and many of these sequences were destroyed as a result of construction of the SACIP. Pools, riffles, and chutes create a wide range of diversity in water depth, water velocity (slack-water, allow vegetation to establish), water surface area, and cross-sectional area, greater availability and persistence of habitat, and improve the food source and variety for microorganisms and invertebrates. Additionally, riffles provide aeration of overflow improving oxygenation and water quality. Incorporated as components integral to the channel modification measure these sequences can be utilized with or without implementation of sediment transport principals.

Construction of “gradient structures” has the effect of reducing the channel slope gradient and velocities, thereby restoring natural functions of pool, riffle, and chute sequences. The gradient structures can be broken down in to separate components. The first component is the impervious structure, which impounds water creating the pool (with or without additional excavation). The second required component is the material placed immediately downstream of the impoundment structure, most likely rock or other suitable material, that provides the "riffle." Another type of gradient structure used for sediment transport consists of the placement of rock without an impervious impoundment structure. A pool could be constructed behind this structure through excavation. The same pool and riffle could also be restored without regard for sediment transport. Under this scenario, placement of rock downstream of the impoundment structure would not be required.

Chutes can also be affected by the design of the impoundment structure. An impoundment structure with a flat crest would cause water to flow evenly over the entire length of the crest and onto the rocks downstream, a characteristic (hydraulically) of a riffle. An impoundment structure having a "concave" crest of a "notch" in the crest would have the effect of concentrating flow characteristic (hydraulically) of a chute. Chutes can also be created through excavation of the base flow channel.

**Boulder and Boulder Clusters**. Boulder and boulder clusters were initially identified as a restoration measure to restore riffle sequences, restore localized slack-water zone, create substrate diversity, and have possible shading effects. Further investigation concluded that boulder and boulder clusters are not natural features within the study area, and therefore cannot be restored. Consequently, they were removed from further consideration.

**Fish Lunkers**. Fish lunkers are in-stream structures constructed of wood, concrete, or other suitable material that mimic undercut banks to provide resting habitat for fish. They are typically located along, and under the toe of the bank. However, in discussion with the resource agencies it was determined that fish lunkers are more likely to benefit non-native and invasive fish species. This is not an objective of the restoration, and fish lunkers were no longer considered.

**Chevron Islands**. Chevrons are in-stream structures that create and/or protect islands in the channel. They can be constructed using a variety of materials and in diverse configurations. Islands restore in-stream habitat, littoral zones, and slack-water zones, and increase the amount of shoreline. Increased river area and cross-sectional diversity in depth and velocity, would provide more extensive habitat and more diverse microhabitats for fish, reptiles, amphibians, and avian species. Additionally, the vegetation on the islands, even if transitory, would provide additional in-stream structure and allochthonous organic materials. The location of chevrons is dictated by stream width (for chevron placement) and suspended sediment loads (for substrate accrual). Further investigation revealed the placement of chevrons would be incompatible with objectives of a stable river and sediment transport, and was not considered further.

**Removal of Espada Dam**. In the 1960's, Espada Channel Dam (River station 185100) was paid for and built by Bexar County after the flood control channel was constructed by the USACE. The Espada Channel Dam was constructed to impound water and allow gravity flow into a historic San Antonio River remnant through two 48-inch diameter pipes in the high berm between the between the channel and the remnant. Flow into this remnant provides the source water which feeds the Espada Acequia constructed in the 1730's. Both the San Antonio River remnant and the Espada Acequia had (and continue to have) water rights that are required to be maintained. The removal of Espada Dam may provide restoration output by allowing unimpeded movement of native fishes along an extensive conduit of comparable water temperature between tributaries and the San Antonio River. Further, permanent de-watering of the existing Davis Lake would provide some benefits to swift water fishes coincident with impacts to slack water fishes due to reduction in surface area and elimination of deep water. Conversion of the lake into a series of interconnected pools, however, would provide benefits, with no impacts, if maximum channel depths and total surface area is preserved. In discussions with the resource agencies, it was determined that Espada Dam and other barriers are not an impediment to the movement of native fishes. Further, given Espada Dam is responsible for the flow of water to the historic river remnant and Espada Acequia (protected by a water right), its removal would require another type of diversion structure to fulfill the water right obligation. The removal of Espada Dam was not considered further as a restoration measure.

**Establishment of Native Riparian Vegetation**. In evaluating the restoration of riparian vegetation, four scenarios comprised of differing vegetation types and densities were evaluated. Three of the vegetation types include trees, and therefore, approximate a forest condition. The fourth condition is comprised exclusively of native grasses and forbs. All three types of woody vegetation would provide varying degrees of habitat benefits associated with the aquatic environment and riparian corridor. Benefits provided to the aquatic environment include: vegetative cover to regulate water temperatures, large woody debris inputs, detritus inputs, additional resources for fish species during periods of inundation, perch sites for aquatic avians, and perch sites for fishing birds (i.e. belted kingfisher). Additionally, woody vegetation would act to slow the velocity of floodwaters, thereby reducing the associated erosive energy. Some of the riparian benefits provided by increasing woody vegetation over the existing condition are: hard and soft mast production, tree and cavity nesting sites, perch sites, and horizontal and vertical cover.

Each vegetative type was assigned a Manning's "n" value to characterize its hydraulic resistance. These Manning's "n" values were developed by professional hydraulic engineers using guidelines considered to be the industry standards (Chow 1959; Arcement 1989). A Manning's "n" Technical Memorandum is located in Appendix C.3.

*Type A vegetation* represents a historic "natural" condition for the San Antonio River's riparian corridor. This type is defined as having an average of 250 trees per acre planted approximately 13 foot on center. Type A would be allowed to follow a natural successional pattern with a fully developed woody under story. Maintenance would be limited to removal of non-native species and hazardous trees and brush. Type A contains the densest, highest resistance vegetation; therefore, it has the highest resistance and impact to the water surface elevation. The Manning's "n" value assigned to Type A is 0.150.

While Type A represents the optimum vegetative regime from a restoration standpoint, it would not be practicable to utilize Type A vegetation throughout the project area due to the performance requirements of the floodway. However, some level of lost aquatic and riparian habitat functions can be restored by using types of woody vegetation which have less hydraulic resistance than Type A. This reduction in hydraulic resistance can be accomplished by varying the density of the over story and under story of the planted areas. Type C and D (described below) were developed to provide variety in the planting pallet and to allow for more restoration than would be practicable with only the use of Type A.

*Type C vegetation* is defined as having an average tree spacing of 25 foot on center, or an average of 70 trees per acre. Type C would have a native grass understory, and some areas of native woody understory and midstory would be allowed to develop. These "no mow" areas would typically run parallel with the river and have clear compensatory conveyance areas located on each side. The remaining understory would be native grasses maintained to a height of 12 to 24 inches. No woody understory would be allowed to develop except in the designated "no mow" areas. The corresponding Manning's "n" value for Type C is a range of 0.075 to 0.085.

*Type D vegetation* is defined as having trees planted at a spacing of 40 foot on center, or approximately 30 trees per acre, on average. The understory component of Type D would be all native grasses mown to a height of 12 to 24 inches. No woody understory would be allowed to develop in Type D. "No mow" areas are not included as an option for this vegetation type. The Manning's "n" value assigned to Type D is 0.055.

Since the flood conveyance constraint precludes a completely wooded riparian corridor, some areas would necessarily have to remain as grassland communities. *Type E vegetation* would be comprised on all native grasses and forbs. Type E vegetation, allowed to grow to heights of 12 to 24 inches would not increase the hydraulic resistance over the existing condition grasses. The increased height would provide slightly higher habitat gains over the existing condition. The conversion of the existing non-native grassland community to Type E vegetation would only occur where it is not hydraulically feasible to apply one of the three woodland types discussed above. However, with the inclusion of native grass/forb meadows, a synergy would be created between the grassland and adjacent woodlands such that the value of each increases. Synergy would also be increased over the existing condition where native grass/forb meadows occur adjacent to the water. Native forbs and grasses allowed to grow to natural heights would provide overhanging vegetative cover at the water's edge, increase insect production for aquatic species, and increase detritus inputs to the aquatic environment. Where Type E is in direct contact with the water's edge, some taller herbaceous species may be allowed.

The establishment of native riparian vegetation would require eradication of non-native, invasive species for both pre- and post construction. Limited chemical (herbicide) treatments and mechanical removal have been identified as effective methods to remove undesirable vegetation.

**Spatial Scaling of Riparian Zones**. A riparian area is a three-dimensional ecotone of interaction that includes the terrestrial and aquatic ecosystems extending down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem and along the water course at a variable width. Neighboring and functionally connected ecosystems within riparian areas give rise to greater biodiversity (Welsch et al. 2000). The high degree of modification to the floodplain within the SACIP has altered the hydrologic regime of the project area, and has eliminated natural floodplain morphology or any potential for the establishment of riparian vegetation in the historic floodplain beyond the flood control channel.

For this study, the riparian zone incorporates all areas within the floodway (bank full condition), including the channel side slopes. This determination was made after reviewing extensive literature and in consultation with the USFWS and the TPWD. Investigations carried out on nearby Salado Creek and Leon Creek support this definition.

The riparian corridors along Salado Creek and Leon Creek in San Antonio were surveyed to better understand the plant community occurring in riparian corridors of south-central Texas. Unlike broad floodplains found in other parts of the country, steep-sided embankments within natural riparian zones are common in this region (Photographs 3-8). These steep embankments are inundated when the river reaches high flood levels, which is indicated by debris in upper branches. Study biologist wanted to answer the question: *Is there vegetation, specifically tree species, occurring on the steep side slopes which are considered dependent upon the hydraulic regime of the river, and therefore, would not survive or thrive in an upland community? Additionally, how far up, and/or away from the river did these species occur?* The team walked transects from water's edge up the steep slopes of the stream's banks noting the species of plants encountered and their distance from and height above the base flow channel of the stream. The information gathered during this field trip helped provide insight and guidance for the restoration of the highly degraded riparian corridor within the project area.

**Photographs 3-8**
**Riparian Corridor Located on Steep Slope Along Leon Creek (left) and Downstream Along the San Antonio River (right)**

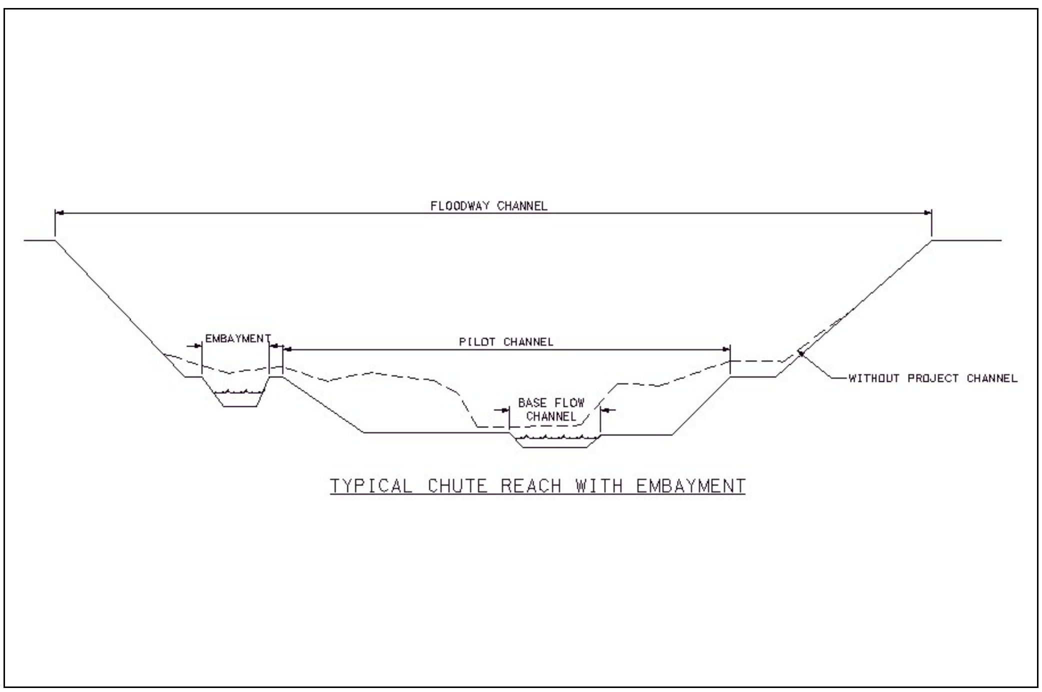

Several tree species considered dependent upon the hydraulic regime of the river were discovered at great distances away from, and above, the baseflow channel in both stream systems visited. Trees species associated with waterways and found throughout the riparian corridor of Leon and Salado Creek's included, common hoptree (*Ptelea trifoliata*), southern magnolia (*Magnolia grandiflora*), box elder (*Acer negundo*), pecan (*Carya illinoinensis*), black walnut (*Juglans nigra*), cottonwood (*Populus deltoides*), and black willow (*Salix nigra*). Many of these trees were located on slopes as much as 20-30 feet vertical and 100-150 feet horizontal from the base flow of the river. The findings from the surveys of Leon and Salado Creeks' riparian corridor mimic similar observations in the undisturbed riparian corridor along the San Antonio River just below the project area. These surveys and observations verify that considering the side slopes of the San Antonio River as riparian is appropriate for this region of Texas.

The above discussion is important in evaluating the impact of the riparian vegetation planted within the floodway channel side slopes, and the impact on the aquatic habitat. In an attempt to quantify the benefit of the riparian vegetation on the channel side slopes to the aquatic habitat, the vegetation was broken down into two zones. Riparian zone one included the vegetation planted within the floodway channel bottom, and riparian zone two is vegetation planted on the channel side slopes.

**Special Aquatic Measures**. Special aquatic measures are those aquatic measures considered that occur outside of the main pilot channel (where opportunities exist), and are not integral to pilot channel design. Habitat Units (HU) that would be gained by these measures would be independent of those gained through channel modifications. However, these special aquatic measures would be dependent on implementation of channel modifications for compliance with other planning constraints (cannot be considered without excavation that would result from implementation of channel modifications). Each special aquatic measure was designed as a unique restoration or enhancement measure that relies on existing resources, and could not be situated in any other location. The special aquatic measures are comprised of the following.

**Embayment**. An embayment is a small area of water in proximity to, but offset from, the main channel providing an area of backwater. These habitats increase surface area and amount of shoreline, diversity in cross-sectional water velocity and depth, and littoral and slack water zones where aquatic vegetation can develop. Vegetated aquatic habitats provide hospitable areas (low velocities, shallow depths) where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow and produce food upon which many aquatic organisms depend. These vegetated areas contain a complex mixture of plants, animals and microorganisms, and provide habitat for insects like dragonflies (*Odonata*), mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), caddis flies (*Trichoptera*) and midges (*Diptera*). They are rich with benthic invertebrates. Aquatic vegetation would provide shade, in-stream structure (inundated forbs, woody debris), and allochthonous organic materials (detritus, terrestrial insects). Fish would benefit from improved cover, spawning substrates, and food sources. The gradation of plants from land into water represents a transition from one environment to another and is known as a zone of succession. Embayments would be accomplished primarily through excavation. The removal or modification of storm drain outfalls provides opportunities for embayments through utilization of an available water resource. A schematic showing typical placement of an embayment measure is provided in Figure 3-3. This is a measure that was carried forward into plan formulation. Design criteria would consider energy dissipation, alternative water sources, and incorporation of wetland features.

**Figure 3-3**
**Pilot Channel Cross Section with Adjacent Embayment**




**Tributary Mouths**. The confluence of tributaries with the San Antonio River could be utilized to create backwater areas in order to maximize aquatic habitat opportunities. These areas would increase the diversity and extent of habitat for water dependent species and provide travel connections to tributaries for fish. There are numerous opportunities to implement this measure, and it has been incorporated into the plan formulation.

**Restore Old River Remnants/Oxbows/Bendways**. During construction of the SACIP, many natural river meanders were cut off from the main channel. Some of these river remnants remain and provide excellent restoration opportunities. If restored, the river remnants would provide refugia (resting areas) from the main channel. Significant ecological gains would take place merely by reconnecting off-channel habitats. Gains in habitat quality within the remnants would occur from increased water depth and velocity. Water quality would be improved from increased circulation of water that minimizes hypoxia and reduces extreme water temperatures associated with stagnant water. These habitats, most of which are well vegetated and provide natural substrates, provide critical feeding, spawning, and rearing grounds largely unavailable in the main channel. Restoring the old river remnants could be accomplished by connecting the existing channel to the old remnants through excavation. A diversion structure may also be necessary to provide and maintain minimal flows. This is a measure considered for plan formulation.

**Wetlands**. Wetlands are among the most productive ecosystems in the world and support diverse communities made up of all major groups of organisms, from microbes to mammals. Functions of wetlands include surface water storage, groundwater recharge, nutrient cycling, filtering of sediments and other suspended solids. The removal or modification of storm drain outfalls could provide opportunities to restore wetlands. Other ephemeral wetlands could be located within the pilot or floodway channel. This is a measure utilized during plan formulation.

## DESIGN CRITERIA

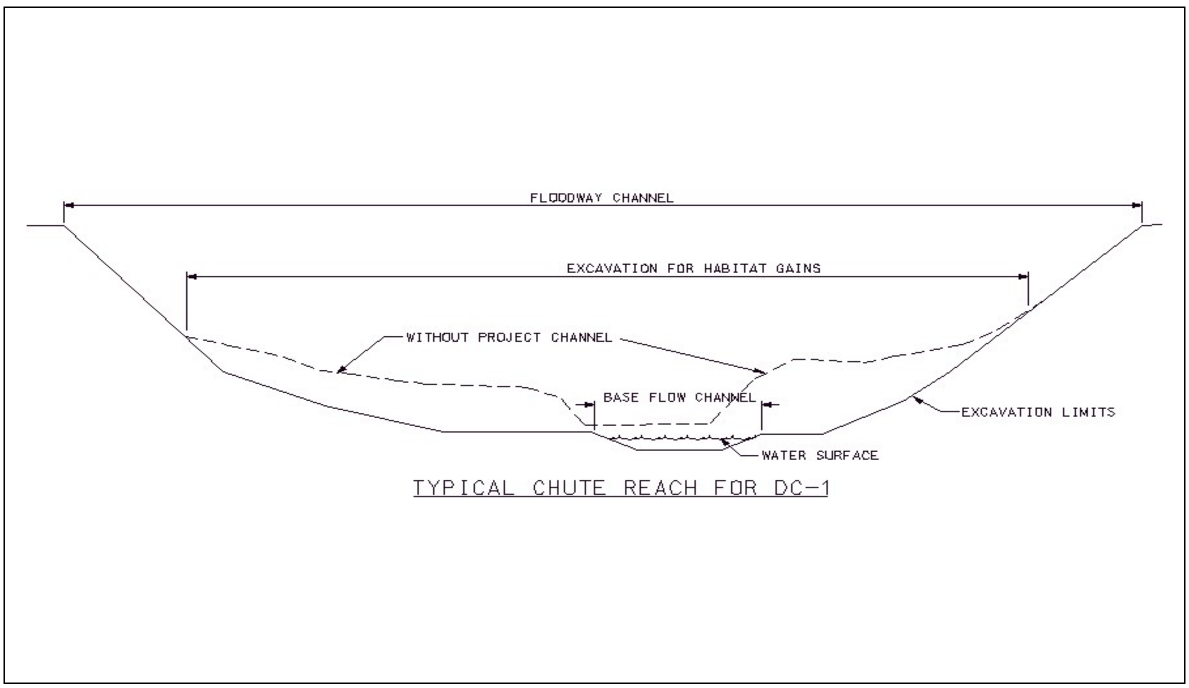
**Floodway Channel Modifications Design Criteria**. Design Condition were identified to capture increments of successively greater amounts of ecosystem restoration. Each design condition (DC) used differing combinations and sizes of pool, riffle, chute sequences to set a hydraulic pallet upon which other restoration measures were formulated. In other words, the evaluation of ecosystem restoration was built upon incremental changes to the hydraulic condition of the river. Following is an expanded discussion of the design conditions.

**Design Condition 0 (DC0)**. Under this condition, the existing channel would remain in its present condition, and no excavation would take place within the floodway channel. The purpose of this DC was to determine what, if any, vegetation could be placed within the existing floodway without violating the planning constraints. *The incremental purpose of DC0 is to improve aquatic and riparian habitat without any excavation.*

**Design Condition 1 (DC1).** The formulation strategy for DC1 was to implement restoration measures resulting in ecosystem benefits without a deliberate adherence to geomorphic and sediment transport design guidelines. DC1 would to improve habitat as reasonably attainable without requiring additional lands or easements beyond the current SACIP. Excavation under DC1 would be necessary to construct riffle structures, increase the depth of pools, increase conveyance within the floodway channel, create wetlands, modify the channel longitudinal slopes for improvement in the long term dominant substrates, and removing concrete rubble from the floodway channel. A typical cross section of the DC1 channel modification is provided in Figure 3-4. *The increment isolated by DC1 is excavation for channel improvements and riparian vegetation.*

**Design Condition 2 (DC2).** The formulation strategy for DC2 is to implement restoration measures and resulting ecosystem benefits in conjunction with the creation of a new pilot channel designed to convey the "effective discharge" or "effective flow" as defined in the San Antonio River Geomorphic & Sediment Transport Technical Memorandum (GSTTM). The "effective flow" is the flow for which the flood frequency and sediment transport capacity are maximized. The goal of the pilot channel design for DC2 was to provide equilibrium of sediment transport and minimize the damaging effects of sediment accumulation and erosion within the system while providing for improved habitat and ecosystem values. The sediment transport pilot channel designed for DC2 would be excavated within the current floodway channel, and would be limited to the bottom width of the floodway channel within the SACIP. The existing floodway channel would not be modified in overall width in order to gain hydraulic conveyance and no additional lands, easements, or rights-of-way would be required.

**Figure 3-4**
**Typical Chute Cross Section for DC1**




A base flow channel would be constructed within the pilot channel to convey the average low flow of 20 cubic feet per second (cfs) and would be located primarily within the river runs. Base flow channels are not applicable within pools or areas backwatered by riffle structures.

Riffle structures would be constructed at specific points along the river and at various heights to control grade and attain the reach average sediment transport equilibrium slope as recommended in the GSTTM. The findings and conclusions of the GSTTM were used as a guide for the design of the pilot channel and base flow channels. Figures 3-5, 3-6, and 3-7 are schematic diagrams of the typical pilot channel design occurring at pools, chutes, and riffles respectively. *The increment isolated in DC2 is the inclusion of the pilot- and base flow channel for sediment transport.*

**Design Condition 3 (DC3)**. The formulation strategy for DC3 is to implement habitat restoration measures resulting in ecosystem benefits utilizing geomorphic and sediment transport design guidelines. Modification to the floodway channel would extend beyond the existing SACIP right-of-way. This would result in greater flood conveyance gains, and implementation of more extensive habitat improvement measures without compromising the flood carrying capacity. *The increment isolated in DC3 is acquisition of real estate and excavation for additional aquatic and riparian benefits.*

**Figure 3-5**
**Typical Pool Cross Section for Pilot Channel**

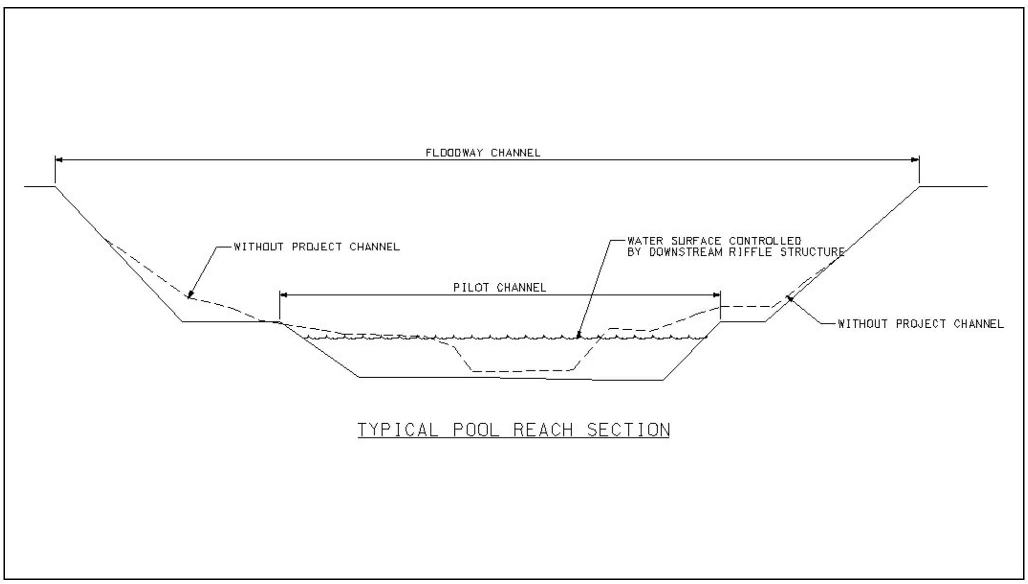


**Figure 3-6**
**Typical Chute Cross Section for Pilot Channel**

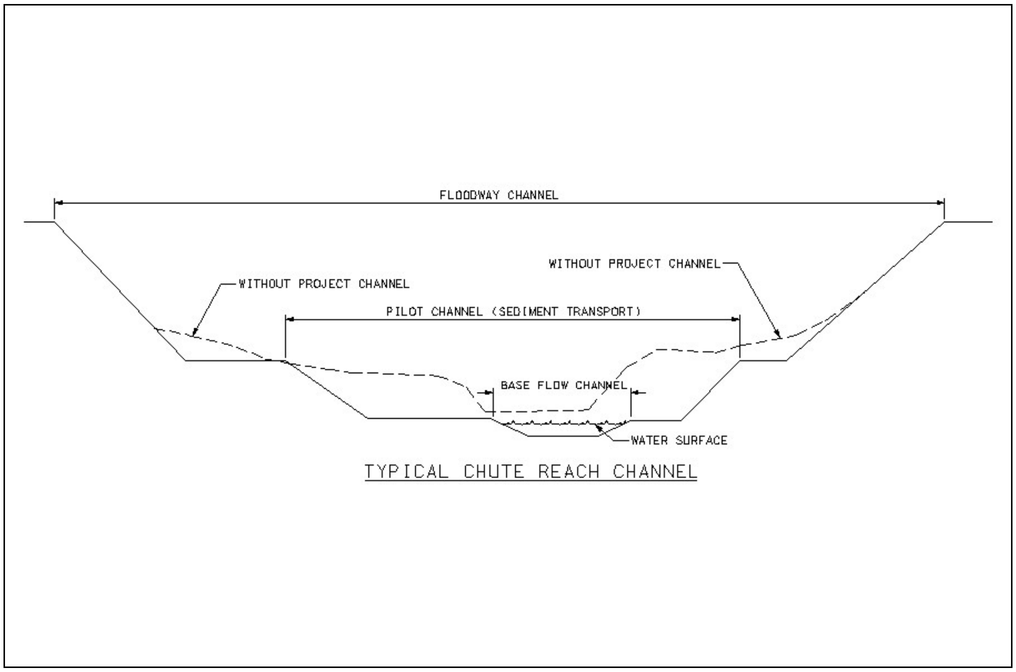
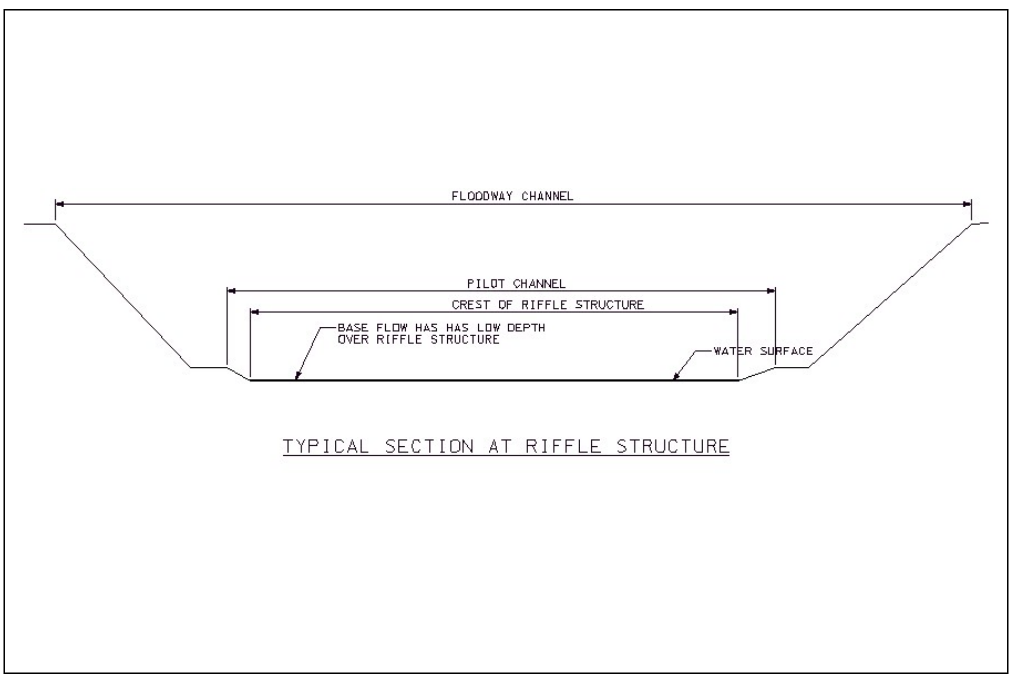



**Figure 3-7**
**Typical Riffle Cross Section for Pilot Channel**



Two plans were formulated upon the DC3 pallet, termed DC3A and DC3B. The first plan, DC3A was developed by the project sponsor as their vision for the restoration of the San Antonio River. Upon review of the plan, the Fort Worth District felt changes could be made increasing the habitat outputs provided by this design condition. Therefore, the DC3B plan was developed as a modification to the DC3A plan, and both were carried throughout the remainder of formulation. The differences in measures between DC3A and DC3B are:

- Riffle structures have an inset base flow channel in DC3A but are removed in DC3B,
- Some larger pool areas in DC3A have been reduced in size to mimic a more natural riverine system in DC3B, and
- The riparian vegetation measures for DC3B were developed using the same criteria used to develop vegetation designs for DC1 and DC2.

**Aquatic Habitat Design Criteria**. Adhering to the incremental purpose of the design conditions, a set of design criteria for aquatic habitat was developed. Using the same aquatic design criteria for each channel design condition ensures differences in aquatic habitat outputs occur as the result of differences in the hydraulic conditions. Aquatic habitat design criteria applying to all hydraulic design conditions are:

- Use existing tributary confluences to provide embayment or tributary mouth habitat.
- Restore open channel to old remnants and provide permanent water supply.
- Restore wetlands in areas where they would be anticipated under natural conditions.

**Cost Effective Incremental Cost Analysis (CE/ICA) Screening of Vegetation Types**. The team determined that to ensure the vegetation layout for all design conditions was developed following a common theme, that a set of design criteria would be developed. The design criteria would provide guidance for what types of vegetation should be considered first based upon best outputs for dollars spent, and it would prioritize locations of highest habitat potential. The criteria would guide the iterative process associated with planting vegetation in a flood control channel. While Type A vegetation, because it represents the most natural condition, biologically provides the best habitat output, it was not certain that Type A would provide the most output for the dollars spent. To facilitate the development of the design criteria, a CE/ICA was performed to establish the vegetation type continuum that should be used when developing the design criteria. The analysis was used to answer the question: "*Is there a type of vegetation, regardless of hydraulic constraints, that provides the best aquatic habitat outputs for the dollars spent?*"

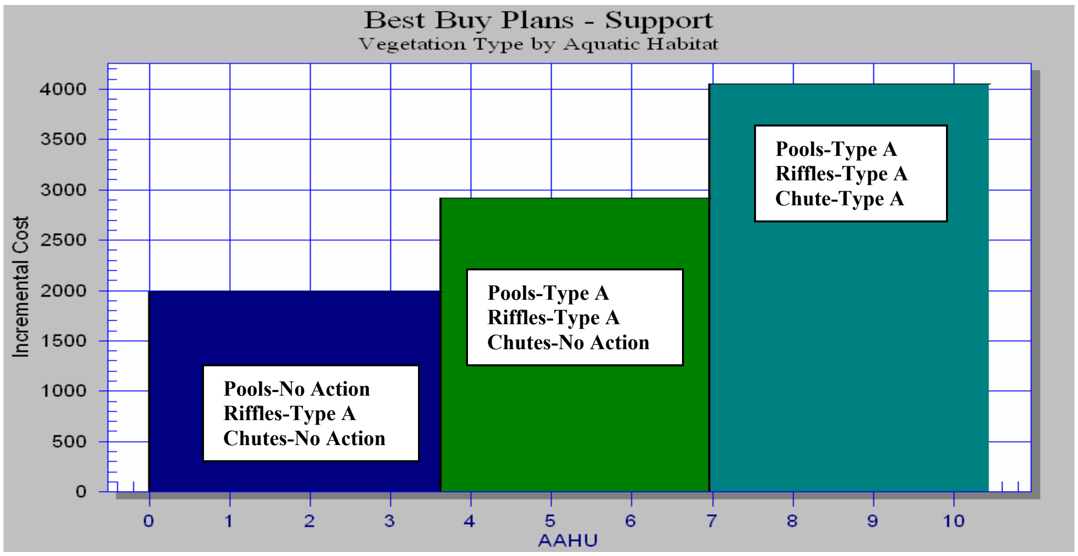
To compile the inputs for this analysis, a set of pools, riffles, and chutes were randomly selected. Four solutions, plus the no action, were developed for each of the three selected habitats types (15 total solutions). These solutions were developed assuming the project area could be completely planted with either all Type A, all Type C, or all Type D adjacent to the identified aquatic habitat types. Input values for the analysis are presented in Table 3-4. Appendix E contains the complete CE/ICA input and output tables for the vegetation type analysis.

**Table 3-4.**
**Vegetation Type Special Screening CE/ICA Input Data**

| Habitat | Code | Vegetation | AAC* | AAHU* |
|---|---|---|---|---|
| Pools | | | | |
| | A2 | Type E | $13,598 | 2.619 |
| | A3 | Type A | $9,761 | 3.343 |
| | A4 | Type D | $12,525 | 3.130 |
| | A5 | Type C | $11,115 | 3.162 |
| Riffles | | | | |
| | B2 | Type E | $10,022 | 2.980 |
| | B3 | Type A | $7,194 | 3.617 |
| | B4 | Type D | $9,232 | 3.375 |
| | B5 | Type C | $8,192 | 3.421 |
| Chutes | | | | |
| | C2 | Type E | $19,665 | 3.022 |
| | C3 | Type A | $14,117 | 3.480 |
| | C4 | Type D | $18,115 | 3.407 |
| | C5 | Type C | $16,075 | 3.291 |

*AAC = Average Annual Cost AAHU = Average Annual Habitat Units

**Figure 3-8**
**IWR-PLAN Graphic Output for Vegetation Analysis**




The results of the analysis concluded Type A vegetation *always* provides the best output for the cost as evidenced by the identification of three best buy alternatives, all having Type A vegetation. The analysis indicates that placing Type A vegetation adjacent to pools, riffles, and chutes provides the best output for the dollars spent. Figure 3-8 shows the graphic output from IWR-PLAN for the vegetation analysis. As a result of the screening analysis, Type A vegetation would be used throughout the project area if there were no hydraulic constraints. However, since there are hydraulic constraints, the less dense woody vegetation, and some native grass areas must be utilized and represent a hydraulic concession. The results of this screening analysis guided the development of riparian design criteria. This criteria was used during the iterative process to identify a vegetation plan for each design condition which produces the greatest net restoration outputs within the hydraulic constraints.

**Riparian Habitat Design Criteria**. Using the same analysis for determining the type and amount of vegetation that would be placed in the riparian zone ensures differences in riparian habitat outputs occur as the result of differences in the hydraulic conditions. Riparian habitat design criteria applying to all three hydraulic design conditions are:

- Follow natural vegetational patterns for a riverine system.
    - Use flood plain meadow or early successional woody overstory vegetation of light density with a limited woody understory vegetation (Type C, D, or E) along inside river bends.
    - Use later successional woody vegetation planted at a closer spacing with a more diverse under- and mid-story (Type A) along outer bends.

- Create synergy between river, riparian corridor, and over bank land cover.
    - Provide connection/corridor from existing over bank habitats to the water.
    - Transition denser over bank vegetation to lighter density vegetation where appropriate or hydraulically necessary.
    - Enlarge patch size of existing over-bank forested areas with emphasis for those in National Park Service ownership.
    - Provide for travel/flight corridor in heavily industrialized/residential area (Lone Star to San Pedro) -- however -- opt for larger patches of dense vegetation to provide interior woodland habitat and reduce edge habitat promoting invasive/exotic vegetational species proliferation.
    - Provide vegetation connection between existing acequia habitats and river.

- Consider relationship between aquatic measures and vegetation.
    - Use densest practicable vegetation around embayments, tributary mouths, and restored remnant channels even where they occur on inside bends
    - Bring densest possible woody vegetation to water's edge where practicable and appropriate to provide vegetational cover, detritus input, and large woody debris.

## HYDRAULIC ANALYSIS OF VEGETATION PLANS

The purpose of hydraulic analyses was to determine how much vegetation could be placed within the floodway channel under the various hydraulic design conditions. The analyses compared without-project water surface elevations with water surface elevations having vegetation in place. Starting with the most desirable vegetation (from a habitat output perspective), if the hydraulic analyses determined an unacceptable increase in water surface elevation, the next desirable vegetation with a lower roughness value was identified and evaluated. This iterative process continued until the best habitat was identified that did not increase the water surface elevation. The following criteria (priority) for making required changes to vegetation due to hydraulic constraints were established:

- Protect dense vegetation designation for restored remnant channels, embayments, and tributary mouths.
- Protect transitional vegetation layers connecting over bank forest to water (i.e. Type A layer transition to Type C).
  - Change Type D occurring along inside bendways to Type E first.
  - If Type C needs to be changed, change those patches that do not connect over bank woodlands to Type D, then Type E if necessary.
  - If absolutely necessary to change designation try changing it to a Type C layer transition to Type D first.
- Lone Star to San Pedro -- provide for a corridor of over story trees, but include one Type A woodland in one location. If hydraulic constraint requires changes, change Type A woodland to Type C first. If still hydraulically infeasible, begin changing Type D vegetation to Type E to protect woodland of Type C.

Hydraulic analyses were completed on the ability to add vegetation within the existing floodway without any type of excavation for any reason (DC0). It was demonstrated that virtually no riparian vegetation could be planted within the floodway as unacceptable increases in the water surface elevation were immediately determined (starting with the most minimal vegetation). A subsequent analysis examined whether the placement of pools (without any excavation) would permit vegetation to be planted. The reasoning was that pools may have a lower roughness value than the existing water, and would allow more roughness (vegetation) to be added to the channel. Again, unacceptable increases in the water surface elevation were present. The conclusion reached was that the planting of woody vegetation within the floodway would require the excavation of material for additional conveyance.

**Restoration Measures for Each Design Condition**. The following is a description of the design conditions and associated riparian vegetation and special aquatic features.

**Design Condition 0**. DC0 was formulated to determine what level of improvement could be made to riparian vegetation without excavation of the floodway or modifications to the aquatic environment. The only measure allowable under the planning constraints for this design condition was a conversion of the mown bermuda grass channel to a native grassland vegetation community. This native grass community would be allowed to grow to heights of 12 to 24 inches, and therefore, it would have a small, but positive, improvement to the aquatic environment. However, historically the riparian corridor would have been a woodland community, and the conversion to a native grassland does not meet with the objective of restoring the riparian corridor to the riverine system. This design condition was not carried forward to the final CE/ICA analysis for consideration because it does not provide any restoration outputs for the riparian corridor, a stated objective, and provides only a small increase in the aquatic outputs over the no-action plan. Implementation of this design condition would leave habitats of the San Antonio riverine system degraded to the point where no visible signs of improvement would occur.

**Design Condition 1**. DC1 is formulated for habitat output without a deliberate adherence to geomorphic and sediment transport design guidelines. DC1 seeks to improve habitat as reasonably attainable without requiring additional lands or easements beyond the current SACIP. Excavation under DC1 would be necessary to construct riffle structures, increase the depth of pools, increase conveyance within the floodway channel, create wetlands, modify the channel longitudinal slopes for improvement in the long term dominant substrates, and removing concrete rubble from the floodway channel. *The increment isolated by DC1 is excavation for channel improvements and riparian vegetation.*

Within DC1, there are 15 riffle structures. These riffle structures are constructed using an inverted "T" concrete wall and are anchored. The height of the concrete wall ranges between 4- and 7-feet, with a crest width between and 5- and 20-feet. The riffles structures extend across the pilot channel for distances between 30- and 210-feet. The top of the concrete wall is level. Riprap is placed on both the up- and downstream face of the concrete wall, on slopes of 20H:1V and 5H:1V, respectively. There are also eight more riffle structures constructed using placed riprap without a concrete wall. The height of the concrete wall ranges between 5- and 7-feet with a crest width between and 1- and 10-feet. The riffles structures extend across the pilot channel for distances between 39- and 50-feet. Table 3-5 displays a summary of the riffle structure characteristics.

This DC also has approximately 1,123,800 cubic yards of excavation including the removal of the existing rubble lining the channel, remnants of a concrete pilot channel and dam, existing sheet pile walls, and modification to the existing San Juan Dam. Lastly, there will be utility (gas, water, sewer, and storm water outfalls) relocations.

In addition, DC1 includes 8 embayments, 1 restored river remnant, and 2 tributary mouths. The embayments are created through modification of storm water outfalls, excavation, and riprap. The San Juan River Remnant represented the only opportunity for restoring connection of a river remnant to the main stem of the river. This remnant is located just above Ashley Road along the east side of the river. Currently, the remnant receives water from the main stem via an underground culvert. Modifications would include re-opening the remnant channel to the Ashley Road Bridge, removal of the underground culvert, and relocation of the culvert headwall. Tributary mouth modifications involve concrete removal, excavation, and riprap reinforcement at the confluence of the tributary and the main stem of the river. Only one of the two tributary mouths occurring in this design condition will be modified, the Conception Creek confluence. The San Pedro tributary mouth would not be directly modified, but improvements to habitat quality may occur as result of other modification occurring in the main stem of the river. Table 3-6 summarizes the location and characteristics of the embayments, river remnant, tributary mouths, and wetland.

Other structural features include erosion protection on the pilot channel over bank required to protect the newly planted vegetation from potential damage from flood events while they become established.

As part of DC1, 230.94 acres of riparian vegetation are restored; and are comprised of 17.25 acres of Type A, 35.43 acres of Type C, 61.10 acres of Type D, and 117.16 acres of Type E. To quantify the benefits of allochthonus material provided by vegetation to the aquatic habitat, the vegetation area was subdivided into riparian zone one and riparian zone two (Table 3-7) as discussed on page 3-33. The restoration of vegetation also includes the removal and control of existing invasive vegetation species and temporary irrigation.

The location of the DC1 restoration measures are indicated on the project maps located in Appendix F

**Design Condition 2**. DC2 is formulated for habitat output in conjunction with the creation of a new pilot channel designed to convey the "effective discharge," defined in the San Antonio River Geomorphic & Sediment Transport Technical Memorandum (GSTTM) as the discharge in which the frequency and sediment transport capacity are maximized. The goal of the pilot channel design for DC2 is to provide equilibrium of sediment transport and minimize the damaging effects of sediment accumulation and erosion within the system while providing for improved habitat and ecosystem values.

The sediment transport pilot channel designed for DC2 would be excavated within the current floodway channel, and limited to the bottom width of the floodway channel within the SACIP. The overall width of the existing floodway channel would not be modified in order to gain hydraulic conveyance and no additional lands, easements or rights-of-way would be required.

A base flow channel would be constructed within the pilot channel to convey the average low flow of 20 cubic feet per second (cfs) and located primarily within the river runs. Base flow channels are not applicable within pools or areas backwatered by riffle structures. Base flow channels would not be used within riffle structures in order to maximize the habitat potential of the riffle. Riffle structures would be constructed at various points along the river and at various heights to control grade and attain the reach average sediment transport equilibrium slope as recommended in the GSTTM. *The increment isolated in DC2 is the inclusion of the pilot for sediment transport.*

Within DC2, there are 30 riffle structures. These riffle structures are constructed using either an inverted "T" concrete wall, or cut limestone block, and both are anchored. The height of the wall ranges between 1.8- and 3.0-feet; with a crest width between and 2- and 10-feet. The riffles structures extend across the pilot channel for distances between 39- and 245-feet. The top of the concrete wall is level. Riprap is placed on both the up- and downstream face of the concrete wall, on slopes of 30H:1V. In addition, there are two concrete weirs (inverted concrete "T" walls), and three areas requiring invert slope protection (placed riprap) as part of the sediment transport function. Table 3-8 displays characteristics of these structures.

**Table 3-5**
**Structural Characteristics**
**Design Condition One**

| station | station | structure type | crest elevation | crest width | crest structure width | d/s structure width | u/s structure width | d/s length | u/s length | d/s slope | u/s slope | elevation d/s end | elevation u/s end | Height of Structure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 170059 | 170164 | Riffle w/ Inverted "T" Concrete Wall | 491 | 5-ft | 120-ft | 95-ft | 80-ft | 60-ft | 20-ft | 20:1 | 5:1 | 488 | 487 | 7-ft |
| 172624 | 172709 | Riffle w/ Inverted "T" Concrete Wall | 493 | 5-ft | 140-ft | 100-ft | 105-ft | 60-ft | 20-ft | 20:1 | 5:1 | 490 | 489 | 7-ft |
| 174696 | 174781 | Riffle w/ Inverted "T" Concrete Wall | 498 | 5-ft | 145-ft | 115-ft | 105-ft | 60-ft | 20-ft | 20:1 | 5:1 | 495 | 494 | 7-ft |
| 177240 | 177325 | Riffle w/ Inverted "T" Concrete Wall | 500 | 5-ft | 185-ft | 145-ft | 145-ft | 60-ft | 20-ft | 20:1 | 5:1 | 497 | 496 | 7-ft |
| 178025 | 178130 | Riffle w/ Inverted "T" Concrete Wall | 502 | 5-ft | 190-ft | 150-ft | 150-ft | 80-ft | 20-ft | 40:1 | 5:1 | 500 | 500 | 6-ft |
| 180078 | 180188 | Riffle w/ Inverted "T" Concrete Wall | 510 | 5-ft | 168-ft | 135-ft | 275-ft | 60-ft | 25-ft | 20:1 | 5:1 | 507 | 505 | 7-ft |
| 180078 | 180188 | Riffle w/ Inverted "T" Concrete Wall | 509 | 60-ft | 30-ft | na | 275-ft | 60-ft | 20-ft | level | 5:1 | 509 | 505 | 4-ft |
| | 182620 | Riffle w/ Inverted "T" Concrete Wall | 512 | 5-ft | 110-ft | 80-ft | 90-ft | 46-ft | 10-ft | 20:1 | 5:1 | 509.7 | 510 | 6.5-ft |
| 189871 | 189996 | Riffle w/ Inverted "T" Concrete Wall | 538 | 5-ft | 210-ft | 195-ft | 175-ft | 60-ft | 20-ft | 30:10 | 5:1 | 536 | 534 | 6-ft |
| 190920 | 191200 | Rock Riffle [1] | 540 | na | na | na | na | 120-ft | | 20:1 | | 534 | 534 | |
| 194500 | 199580 | Riffle w/ Inverted "T" Concrete Wall | 543 | 10-ft | 125-ft | 70-ft | 105-ft | 60-ft | 10-ft | 20:1 | level | 541 | 541.8 | 6-ft |
| 198200 | 198280 | Riffle w/ Inverted "T" Concrete Wall | 551.8 | 10-ft | 117-ft | 100-ft | 105-ft | 60-ft | 10-ft | 20:1 | 5:1 | 548.8 | 549.8 | 7-ft |
| 200593 | 200803 | Riffle w/ Inverted "T" Concrete Wall | 558 | 10-ft | 105-ft | 85-ft | 93-ft | 60-ft | 10-ft | 20:1 | 5:1 | 555 | 556 | 7-ft |
| 203584 | 203664 | Riffle w/ Inverted "T" Concrete Wall | 565 | 10-ft | 117-ft | 95-ft | 105-ft | 60-ft | 10-ft | 20:1 | 5:1 | 562 | 563 | 7-ft |
| 205261 | 205341 | Riffle w/ Inverted "T" Concrete Wall | 569.4 | 10-ft | 115-ft | 95-ft | 103-ft | 60-ft | 10-ft | 20:1 | 5:1 | 568.4 | 567.4 | 7-ft |
| 206080 | 206170 | Riffle w/ Inverted "T" Concrete Wall | 572 | 20-ft | 173-ft | 123-ft | 170-ft | 60-ft | 10-ft | 20:1 | 5:1 | 569 | 570 | 7-ft |
| 206670 | 206835 | Rock Riffle | 579 | 1-ft | 50-ft | 26-ft | 50-ft | 116-ft | 30-ft | 20:1 | 5:1 | 573.2 | 579.1 | 7-ft |
| 207128 | 207208 | Rock Riffle | 581.3 | 1-ft | 45-ft | 36-ft | 45-ft | 30-ft | 30-ft | 20:1 | 0.24% | 579.8 | 581.4 | 5-ft |
| 207526 | 207606 | Rock Riffle | 583.7 | 1-ft | 42-ft | 36-ft | 42-ft | 30-ft | 30-ft | 20:1 | 0.24% | 582.2 | 583.8 | 5-ft |
| 207726 | 207827 | Rock Riffle | 584.8 | na | 50-ft | 45-ft | 38-ft | 29-ft | 10-ft | 3% | 0.24% | 584 | 583.3 | na |
| | | Rock Riffle | 588.3 | 10-ft | 50-ft | 35-ft | 38-ft | 60-ft | 10-ft | 20:1 | 5:1 | 585.3 | 586.3 | 7-ft |
| 209785 | 209885 | Rock Riffle | 591.8 | 10-ft | 39-ft | 28-ft | 27-ft | 60-ft | 10-ft | 20:1 | 5:1 | 588.8 | 589.8 | 7-ft |
| 211210 | 211310 | Rock Riffle | 596 | 10-ft | 45-ft | 25-ft | 33-ft | 60-ft | 10-ft | 20:1 | 5:1 | 593 | 594 | 7-ft |
| 212013 | 212113 | Rock Riffle | 600 | na | 50-ft | 30-ft | na | 80-ft | na | 20:1 | 5:1 | 596 | na | na |

**Table 3-6**
**Embayment, River Remnant, Tributary Mouths, and Wetland Characteristics**
**Design Condition One**

| Station | Station | Aquatic Feature Name | Acres |
|---|---|---|---|
| 2051+00 | 2047+00 | Conception Park Embayment | 0.25 |
| 2051+00 | 2045+60 | Conception Creek Embayment | 0.47 |
| 2045+60 | 2043+00 | Conception Creek Trib Mouth | 0.49 |
| 2004+00 | 1993+00 | E. Southcross Ave. Embayment | 0.48 |
| 1961+00 | 1954+70 | Mission Road Embayment | 0.84 |
| 1943+50 | 1936+50 | E. White Ave. Embayment | 0.5 |
| 1922+70 | 1913+60 | Hot Wells Embayment | 0.77 |
| 1801+83 | 1801+83 | San Juan Restored Remnant | 0.5 |
| 1794+50 | 1781+50 | Ashley Road Wetland | 6.05 |
| 1770+00 | 1756+00 | Brown Park Embayment | 1.9 |
| 1714+00 | 1706+00 | Mission Espada Embayment | 0.67 |

**Table 3-7**
**Acres of Riparian Vegetation Types by Zone**
**Design Condition One**

| | Type A | Type C | Type D | Type E | Total |
|---|---|---|---|---|---|
| Zone 1 | 10.77 | 22.63 | 36.81 | 56.66 | 126.86 |
| Zone 2 | 6.48 | 12.80 | 24.29 | 60.50 | 104.07 |
| Total | 17.25 | 35.43 | 61.10 | 117.16 | 230.93 |

**Table 3-8**
**Structure Characteristics**
**Design Condition 2, 3A, and 3B**

| Approx Station | Approx Station | Structure Type | Approximate Crest Elevation | Approximate Crest Width | Structure Width @ Crest | Downstream Length | Upstream Length | Downstream Slope | Upstream Slope | Approximate Elevation @ D/S End | Approximate Elevation @ U/S End | Approximate Height of Structure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1707+57 | 1709+23 | Rock Riffle w/ Cut Limestone Wall | 490 | 2-feet | 114-feet | 81 | 81 | 30:01:00 | 30:01:00 | 485.2 | 488.5 | 2.7 |
| 1721+50 | 1723+62 | Rock Riffle w/ Cut Limestone Wall | 491.9 | 2-feet | 115 | 105 | 105 | 30:01:00 | 30:01:00 | 488.2 | 488.5 | 3.5 |
| 1747+56 | 1748+90 | Rock Riffle w/ Cut Limestone Wall | 493.7 | 2-feet | 108 | 66 | 66 | 30:01:00 | 30:01:00 | 490.1 | 492.1 | 2.2 |
| 1759+23 | 1760+15 | Rock Riffle w/ Cut Limestone Wall | 496.3 | 2-feet | 124 | 45 | 45 | 30:01:00 | 30:01:00 | 493.9 | 495.2 | 1.5 |
| 1773+78 | 1773+83 | Inverted T Weir | 502.8 | 5-feet | 245 | na | na | na | na | na | na | 6.8 |
| 1786+13 | 1793+71 | Invert Slope Protection | 505.5 | na | na | na | na | na | na | na | na | na |
| 1796+13 | 1798+03 | Invert Slope Protection | 509.5 | na | na | na | na | na | na | na | na | na |
| 1798+50 | 1798+55 | Inverted T Weir | 510.2 | 5-feet | 179 | na | na | na | na | na | na | 6 |
| 1810+85 | 1811+77 | Rock Riffle w/ Cut Limestone Wall | 509.9 | 2-feet | 120 | 45 | 45 | 30:01:00 | 30:01:00 | 508.2 | 508.3 | 1.5 |
| 1826+20 | 1827+60 | Rock Riffle w/ Cut Limestone Wall | 512.3 | 2-feet | 136 | 69 | 69 | 30:01:00 | 30:01:00 | 509 | 510.8 | 2.3 |
| 1838+50 | 1839+84 | Rock Riffle w/ Cut Limestone Wall | 514.3 | 2-feet | 136 | 66 | 66 | 30:01:00 | 30:01:00 | 511 | 513.2 | 2.2 |
| 1910+45 | 1914+07 | Rock Riffle w/ Cut Limestone Wall | 538 | 2-feet | 142 | 180 | 180 | 30:01:00 | 30:01:00 | 529.8 | 533.3 | 6 |
| 1932+07 | 1933+47 | Rock Riffle w/ Cut Limestone Wall | 539.1 | 2-feet | 114 | 69 | 69 | 30:01:00 | 30:01:00 | 536.5 | 537.1 | 2.3 |
| 1947+47 | 1949+83 | Rock Riffle w/ Inverted T Concrete Wall | 543.3 | 10-feet | 134 | 113.1 | 113.1 | 30:01:00 | 30:01:00 | 538.7 | 539.5 | 3.8 |
| 1956+63 | 1958+15 | Rock Riffle w/ Cut Limestone Wall | 543 | 2-feet | 120 | 75 | 75 | 30:01:00 | 30:01:00 | 540.2 | 540.7 | 2.5 |
| 1971+19 | 1973+01 | Rock Riffle w/ Cut Limestone Wall | 545.6 | 2-feet | 100 | 90 | 90 | 30:01:00 | 30:01:00 | 542.5 | 542.2 | 3 |
| 1976+43 | 1977+43 | Invert Slope Protection under Bridge | na | na | na | na | na | na | na | na | na | na |
| 1988+48 | 1990+18 | Rock Riffle w/ Cut Limestone Wall | 548.7 | 2-feet | 110 | 84 | 84 | 30:01:00 | 30:01:00 | 545.3 | 546.3 | 2.8 |
| 1997+79 | 1999+49 | Rock Riffle w/ Cut Limestone Wall | 550.4 | 2-feet | 110 | 84 | 84 | 30:01:00 | 30:01:00 | 547.1 | 547.9 | 2.8 |
| 2007+23 | 2008+75 | Rock Riffle w/ Cut Limestone Wall | 552.2 | 2-feet | 100 | 75 | 75 | 30:01:00 | 30:01:00 | 548.5 | 550 | 2.5 |
| 2018+49 | 2020+55 | Rock Riffle w/ Cut Limestone Wall | 555.6 | 2-feet | 110 | 102 | 102 | 30:01:00 | 30:01:00 | 551.7 | 552.6 | 3.4 |
| 2028+93 | 2030+45 | Rock Riffle w/ Cut Limestone Wall | 557.5 | 2-feet | 102 | 75 | 75 | 30:01:00 | 30:01:00 | 553.8 | 555.9 | 2.5 |
| 2039+16 | 2040+74 | Rock Riffle w/ Cut Limestone Wall | 560.9 | 2-feet | 110 | 78 | 78 | 30:01:00 | 30:01:00 | 557.7 | 558.6 | 2.6 |
| 2046+33 | 2048+11 | Rock Riffle w/ Inverted T Concrete Wall | 565.6 | 10-feet | 118 | 84 | 84 | 30:01:00 | 30:01:00 | 558.6 | 561 | 2.8 |
| 2055+98 | 2057+76 | Rock Riffle w/ Inverted T Concrete Wall | 568.3 | 10-feet | 115 | 84 | 84 | 30:01:00 | 30:01:00 | 563 | 565.5 | 2.8 |
| 2061+99 | 2063+33 | Rock Riffle w/ Cut Limestone Wall | 571 | 2-feet | 60 | 66 | 66 | 30:01:00 | 30:01:00 | 568.2 | 569.1 | 2.2 |
| 2067+24 | 2069+60 | Rock Riffle w/ Inverted T Concrete Wall | 576.6 | 10-feet | 39 | 113.1 | 113.1 | 30:01:00 | 30:01:00 | 571 | 572.8 | 3.8 |
| 2074+58 | 2076+38 | Rock Riffle w/ Inverted T Concrete Wall | 582.1 | 10-feet | 43 | 85.2 | 85.2 | 30:01:00 | 30:01:00 | 575.5 | 579.3 | 2.8 |
| 2080+48 | 2082+24 | Rock Riffle w/ Inverted T Concrete Wall | 585.7 | 10-feet | 36 | 83.7 | 83.7 | 30:01:00 | 30:01:00 | 580.2 | 582 | 2.8 |
| 2087+30 | 2089+06 | Rock Riffle w/ Inverted T Concrete Wall | 587.8 | 10-feet | 42 | 83.1 | 83.1 | 30:01:00 | 30:01:00 | 582.1 | 585 | 2.8 |
| 2092+66 | 2094+40 | Rock Riffle w/ Inverted T Concrete Wall | 590.6 | 10-feet | 67 | 81.9 | 81.9 | 30:01:00 | 30:01:00 | 585.5 | 587.9 | 2.7 |
| 2099+57 | 2101+30 | Rock Riffle w/ Inverted T Concrete Wall | 593.5 | 10-feet | 64 | 81.3 | 81.3 | 30:01:00 | 30:01:00 | 588.8 | 590.8 | 2.7 |
| 2105+93 | 2107+67 | Rock Riffle w/ Inverted T Concrete Wall | 596.6 | 10-feet | 76 | 82.2 | 82.2 | 30:01:00 | 30:01:00 | 592.1 | 593.9 | 2.7 |
| 2113+10 | 2114+27 | Rock Riffle w/ Inverted T Concrete Wall | 600 | 10-feet | 58 | 53.7 | 53.7 | 30:01:00 | 30:01:00 | 594.8 | 596.4 | 1.8 |
| 2118+42 | 2120+16 | Rock Riffle w/ Inverted T Concrete Wall | 602.1 | 10-feet | 45 | 82.2 | 82.2 | 30:01:00 | 30:01:00 | 596.4 | 599.4 | 2.7 |

This DC also has approximately 1,040,600 cubic yards of excavation, including the removal of the existing rubble lining the channel, remnants of a concrete pilot channel and dam, existing sheet pile walls, and modification to the existing San Juan Dam. There will be utility (gas, water, and sewer relocations), and 33 storm water outfall modifications. The disturbed areas within the pilot channel will be vegetated with 33.62 acres of Type E vegetation.

In addition, DC2 includes five embayments; two restored river remnants, and five tributary mouths. Table 3-9 summarizes the locations and features of these measures. The embayments are created through modification of storm water outfalls, excavation, and riprap. The San Juan River Remnant is one opportunity for restoring connection of a river remnant to the main stem of the river. This remnant is located just above Ashley Road along the east side of the river. Currently, the remnant receives water from the main stem via an underground culvert. Modifications would include re-opening the remnant channel to the Ashley Road Bridge, removal of the underground culvert, and relocation of the culvert headwall. The other remnant is located just below I-410 along the west side of the river. This remnant receives water via an underground culvert, but only during periods of high flow. Modifications to accomplish reconnection would include re-opening the upstream end of the remnant channel and removal of the underground culverts. Tributary mouth modifications involve concrete removal, excavation, and riprap reinforcement at the confluence of the tributary and the main stem of the river. Four tributary mouths occurring in this design condition would be modified. The San Pedro tributary mouth would not be directly modified, but improvements to habitat quality may occur as result of other modification occurring in the main stem of the river. Other structural features include erosion protection on the pilot channel over bank required to protect the newly planted vegetation from potential damage from flood events while they become established.

**Table 3-9**
**Embayment, River Remnant, Tributary Mouths, and Wetland Characteristics**
**Design Condition Two**

| Station | Station | Aquatic Feature Name | Acres |
|---|---|---|---|
| 2044+00 | 2044+00 | Conception Creek Trib Mouth | 0.29 |
| 2025+00 | 2018+00 | Ballpark Embayment | 0.34 |
| 1993+50 | 1992+00 | Golf Course Embayment | 0.05 |
| 1941+00 | 1934+00 | Mission County Park Embayment | 0.44 |
| 1828+00 | 1828+00 | San Juan Trib Mouth | 0.09 |
| 1810+00 | 1810+00 | Ashley Road Trib Mouth | 0.15 |
| 1806+00 | 1806+00 | No Name Trib Mouth | 0.17 |
| 1802+00 | 1802+00 | San Juan Restored Remnant | 0.51 |
| 1781+00 | 1796+00 | Ashley Road Wetland | 7.32 |
| 1733+00 | 1733+00 | Mission Espada Restored Remnant | 0.43 |
| 1760+00 | 1754+50 | Brown park Embayment | 0.68 |
| 1713+00 | 1704+00 | Mission Espada Embayment | 1.14 |

As part of DC2, 198.83 acres of riparian vegetation are restored; and are comprised of 20.33 acres of Type A, 40.40 acres of Type C, 64.87 acres of Type D, and 73.23 acres of Type E. Acres of Zone 1 and Zone 2 vegetation are displayed in Table 3-10**.** The restoration of vegetation also includes the removal of existing invasive vegetation species, weed control, and temporary irrigation. The location of the identified restoration measures are indicated on the project maps located in Appendix F.

**Table 3-10**
**Acres of Riparian Vegetation Types by Zone**
**Design Condition Two**

| | Type A | Type C | Type D | Type E | Total |
|---|---|---|---|---|---|
| Zone 1 | 10.51 | 19.10 | 29.31 | 35.46 | 94.38 |
| Zone 2 | 9.82 | 21.30 | 35.56 | 37.77 | 104.45 |
| Total | 20.33 | 40.40 | 64.87 | 73.23 | 198.83 |

**Design Condition 3A**. DC3 is formulated for habitat output utilizing the GSTTM design guidelines, but modification to the floodway channel would extend beyond the existing SACIP right-of-way. This would result in greater flood conveyance gains, and implementation of more extensive habitat improvement measures without compromising the flood carrying capacity. *The increment isolated in DC3 is acquisition of real estate and additional excavation for habitat improvement.*

Within DC3A, there are 30 riffle structures. These riffle structures are constructed using either an inverted “T” concrete wall, or cut limestone block, and both are anchored. The height of the wall ranges between 1.8- and 3.0-feet; with a crest width between and 2- and 10-feet. The riffles structures extend across the pilot channel for distances between 39- and 245-feet. The top of the concrete wall is concave to focus flow over a narrower band across the structure. Riprap is placed on both the up- and downstream face of the concrete wall, on slopes of 30H:1V. The downstream riprap is also concaved to concentrate flows into a narrower channel. There are two concrete weirs (inverted concrete “T” walls), and three areas requiring invert slope protection (placed riprap) for the sediment transport function.

This DC also has approximately 4,021,800 total cubic yards (cy) of excavation, 1,040,600 for the pilot channel, 2,769,200 cy to provide additional conveyance for the placement of vegetation, and 212,000 cy for pools. DC3A includes the removal of the existing rubble lining the channel, remnants of a concrete pilot channel and dam, existing sheet pile walls, and modification to the existing San Juan Dam. The disturbed areas within the pilot channel will be vegetated with 45.74 acres of Type E vegetation.

There will be utility (gas, water, and sewer relocations) and 85 storm water outfall modifications (53 from the pilot channel excavation and 32 from the additional conveyance excavation. Additional conveyance for vegetation is also provided by two bridge modifications. The existing slope concrete paving under the East Southcross and East White Bridges would be replaced with a steeper slope. Lastly, DC3A includes the relocation of a portion of Mission Parkway, sidewalks, and parking lots.

DC3A includes 9 embayments, two restored river remnants, and six tributary mouths. Table 3-11 shows the locations of these measures. The embayments are restored by modifying storm water outfalls and excavation. The San Juan River Remnant is one opportunity for reconnecting a river remnant to the main stem of the river. This remnant is located just

**Table 3-11**
**Embayment, River Remnant, Tributary Mouths, and Wetland Characteristics**
**Design Condition 3A and 3B**

| Station | Station | Aquatic Feature Name | Acres |
|---|---|---|---|
| 2047+00 | 2045+00 | Conception Creek North Embayment | 0.15 |
| 2045+00 | 2045+00 | Conception Creek Trib Mouth | 0.14 |
| 2042+00 | 2023+00 | Conception Creek South Embayment | 1.57 |
| 2023+00 | 2023+00 | Ball Park Trib Mouth | 0.09 |
| 2020+00 | 2016+00 | Ball Park Embayment | 0.43 |
| 1992+00 | 1992+00 | Golf Course Trib Mouth | 0.1 |
| 1942+00 | 1937+00 | Hotwells North Embayment | 0.12 |
| 1937+00 | 1937+00 | Hotwells Trib Mouth | 0.11 |
| 1937+00 | 1927+00 | Hotwells South Embayment | 0.97 |
| 1832+00 | 1828+00 | Berg's Mill Embayment | 0.38 |
| 1827+00 | 1827+00 | Berg's Mill Trib Mouth | 0.10 |
| 1817+00 | 1810+00 | Ashley Road Embayment | 0.66 |
| 1802+00 | 1798+00 | San Juan Restored Remnant (1) | 0.81 |
| 1797+86 | 1787+76 | Ashley Road Wetland (2) | 7.46 |
| 1758+00 | 1756+00 | Brown Park Embayment | 0.13 |
| 1733+00 | 1733+00 | Mission Espada Restored Remnant | 0.58 |
| 1718+00 | 1706+50 | Mission Espada Embayment | 0.72 |

(1) San Juan restored remnant acreage for DC3B is 0.94
(2) Ashley Road wetland acreage for DC3B is 7.75

above Ashley Road along the east side of the river. Currently, the remnant receives water from the main stem via an underground culvert. Modifications would include re-opening the remnant channel to the Ashley Road Bridge, removal of the underground culvert, and relocation of the culvert headwall. The other remnant is located just below I-410 along the west side of the river. This remnant receives water via an underground culvert, but only during periods of high flow. Modifications to accomplish reconnection would include re-opening the upstream end of the remnant channel and removal of the underground culverts. Tributary mouth modifications involve concrete removal, excavation, and riprap reinforcement at the confluence of the tributary and the main stem of the river. Five tributary mouths in this design condition will be modified. The San Pedro tributary mouth would not be directly modified, but improvements to habitat quality may occur as result of other modification occurring in the main stem of the river. Other structural features include erosion protection on the pilot channel over banks to protect new vegetation from damage during flood events.

As part of DC3A, 305.04 acres of riparian vegetation are restored; and are comprised of 34.66 acres of Type A, 73.20 acres of Type C, 187.44 acres of Type D, and 9.74 acres of

Type E. Acreage of zone one and zone two vegetation is shown in Table 3-12**.** The restoration of vegetation also includes the removal of existing invasive vegetation species, weed control, and temporary irrigation. The location of the identified restoration measures are indicated on the project maps located in Appendix F.

**Table 3-12**
**Acres of Riparian Vegetation Types by Zone**
**Design Condition 3A**

| | Type A | Type C | Type D | Type E | Total |
|---|---|---|---|---|---|
| Zone 1 | 7.54 | 20.68 | 114.73 | 6.76 | 149.71 |
| Zone 2 | 27.12 | 52.52 | 72.71 | 2.98 | 155.33 |
| Total | 34.66 | 73.20 | 187.44 | 9.74 | 305.04 |

**Design Condition 3B**. DC3B is the same as DC3A except for smaller individual pools (212,000 cy less excavation), and a different vegetation composition and layout. Table 3-11 shows the approximate locations of tributary mouths, embayments, and restored remnants for DC3B. Of the 320.14 acres of riparian vegetation restored in DC3B, 53.93 acres are Type A, 90.58 acres are Type C, 120.15 acres are Type D, and 55.48 acres are Type E. Acreage of zone 1 and zone 2 vegetation is shown in Table 3-13. Vegetation restoration includes removal of invasive vegetation, weed control, and temporary irrigation. The location of the identified restoration measures are indicated on the project maps located in Appendix F.

Table 3-14 is a comparison of environmental features for each design condition.

**Table 3-13**
**Acres of Riparian Vegetation Types by Zone**
**Design Condition 3B**

| | Type A | Type C | Type D | Type E | Total |
|---|---|---|---|---|---|
| Zone 1 | 19.51 | 32.41 | 64.43 | 44.56 | 160.91 |
| Zone 2 | 34.42 | 58.17 | 55.72 | 10.92 | 159.23 |
| Total | 53.93 | 90.58 | 120.15 | 55.48 | 320.14 |

## HABITAT EVALUATION

Habitat Evaluation Procedure (HEP) is a species-habitat approach to impact assessment. Habitat quality for selected evaluation species is derived with a Habitat Suitability Index (HSI). This HSI is derived from an evaluation of key habitat variables, or Suitability Indexes (SI) to supply the life requisites of selected species. Optimum conditions are those associated with the highest potential densities, or the carrying capacity, of the species within a defined habitat area. The index ranges from 0.0 to 1.0, with 1.0 representing the highest habitat quality possible. A Habitat Unit (HU) is the product of the HSI multiplied by an area (acre) of available habitat. HSIs and HUs were developed for different times during the

**Table 3-14**
**Comparison of Environmental Features for Each Design Condition**

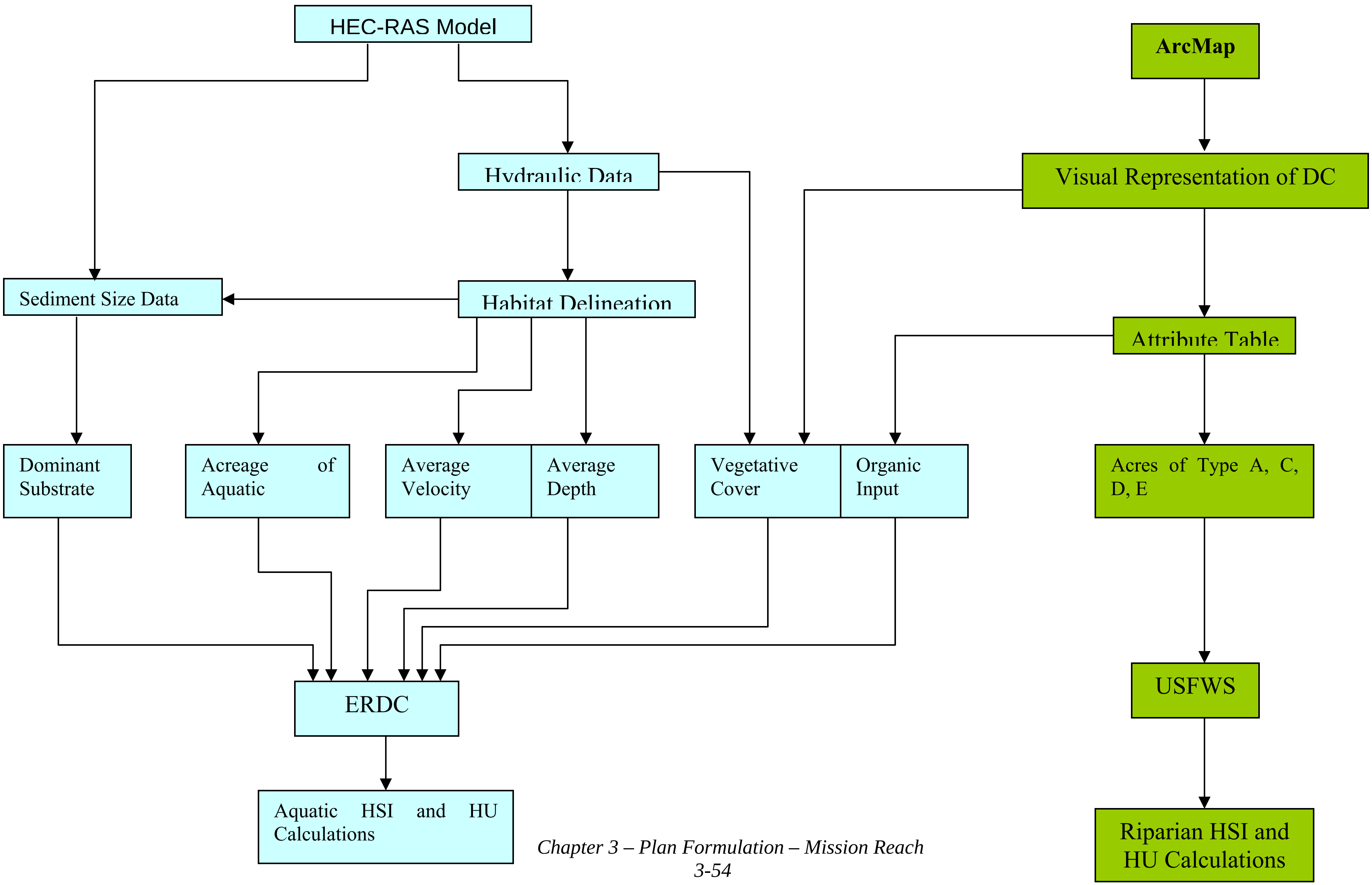
| Measures Identified | Design Condition 0 | Design Condition 1 | Design Condition 2 | Design Condition 3A | Design Condition 3B |
|---|---|---|---|---|---|
| **Channel Modifications:** | | | | | |
| Acres of Pool | 39.37 | 71.93 | 70.29 | 67.79 | 68.89 |
| Acres of Riffle | 1.26 | 4.68 | 14.51 | 0.28 | 18.42 |
| Acres of Chute | 19.34 | 16.90 | 7.72 | 15.80 | 9.43 |
| Acres of Scour Pool | 1.25 | 1.17 | 1.51 | 1.53 | 1.55 |
| Acres of Chute below pool | 0.37 | 0.00 | 0.12 | 0.00 | 0.00 |
| **Riparian Vegetation:** | | | | | |
| Riparian Zone 1 | | | | | |
| Acres of Type A | 0.00 | 10.77 | 10.51 | 7.54 | 19.51 |
| Acres of Type C | 0.00 | 22.63 | 19.10 | 20.68 | 32.41 |
| Acres of Type D | 0.00 | 36.81 | 29.31 | 114.73 | 64.43 |
| Acres of Type E | 162.82 | 56.65 | 35.46 | 6.76 | 44.56 |
| Riparian Zone 2 | | | | | |
| Acres of Type A | 0.00 | 6.48 | 9.82 | 27.12 | 34.42 |
| Acres of Type C | 0.00 | 12.80 | 21.30 | 52.52 | 58.17 |
| Acres of Type D | 0.00 | 24.29 | 35.56 | 72.71 | 55.72 |
| Acres of Type E | 115.49 | 60.50 | 37.77 | 2.98 | 10.92 |
| **Special Aquatic Measures:** | | | | | |
| Acres of Embayments | 0 | 5.88 | 2.65 | 5.13 | 5.13 |
| Acres of Tributary Mouths | 0 | 0.49 | 0.70 | 0.64 | 0.64 |
| Acres of Wetlands | 0 | 6.05 | 7.32 | 7.46 | 7.75 |
| Acres of Restored Remnants | 0 | 0.5 | 0.94 | 1.39 | 1.52 |

period of analysis (at year 1, 5, 15, 25, and 50), and HUs are annualized to estimate an average annual habitat unit (AAHU). Therefore, HEP provides information for two general types of wildlife habitat comparisons. The first is the relative value of different areas at the same point in time. The second is the relative value of the same area at future points in time. Therefore, the impact of land and water use changes on wildlife habitat can be estimated.

Figure 3-9 is a graphical representation of the process used to determine habitat values and gains under without- and with-project conditions.

**Evaluation of Aquatic Habitat**. The U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), San Antonio River Authority (SARA), U.S. Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), Texas Council on Environmental Quality (TCEQ), and the Fort Worth District all participated in the development of the aquatic HEP. Tom Hardy (HEP developer, USFWS) was consulted on the analysis methodology. ERDC conducted field studies of the San Antonio River during 2002 and 2003 to gather data related to physical habitat and fish communities. The purpose

**Figure 3-9**
**Determination of Aquatic and Riparian Outputs for Identified Measures**



of the data was to develop aquatic habitat models for the without- (existing and future) and with-project conditions. This approach required five sets of information:

- Establishment of a base flow condition.
- Identification of aquatic habitat categories.
- Identification of fish species guilds characteristic of each habitat category.
- Prediction of habitat variables for each habitat category.
- Habitat Suitability Index (HSI) models for each fish guild.

**Establishment of Base Flow Condition**. Base flow separation was performed on daily average flow data for the available period of record at the South Alamo and IH-410 gages using base flow index (BFI). The median baseflow at the South Alamo gage was 19.4 cfs, and the median baseflow at IH-410 was 21.2 cfs, indicating slightly gaining conditions over the intervening reach. The implication is that if it is desired to maintain a full channel for low flow conditions, the minimum channel dimensions should consider 20 cfs for the base flow channel, assuming flows that exceed the base flow design would spread out over the pilot channel.

**Identification of Aquatic Habitat Categories.** Eight existing aquatic habitat categories were identified by ERDC within Mission Reach. They are pools, riffles, chutes, scour pools, chutes below pools, embayments, river remnants, and tributary mouths. The identification of pools, riffles, chutes, scour pools, and chutes below pools were based on hydraulic characteristics within the river, and to some extent the location of in-channel structures (weirs, grade control structures, etc.). Appendix D contains tables displaying hydraulic data used to delineate these habitats for the without- and with-project conditions. The hydraulic models did not address off-channel habitats such as embayments, river remnants, and tributary mouths. They were identified based on estimated acreages of surface water, amount of vegetation, velocity, depth, and substrates recorded during field studies. The following is a brief description of each type of aquatic habitat.

*Pool* - A segment of the river that is characterized by holding a constant water surface elevation, has low-velocity water and a smooth surface.
*Scour Pool* - A portion of the river characterized by a deep pool forming below the plunge point of a structure.
*Riffle* - A segment of the river that is characterized by wide, shallow, fast-moving water broken by the presence of rocks.
*Chute (or Run)* - A reach of the river characterized by fast-flowing, low turbulence water, having consistent depths and velocity.
*Chute below pool* - The downstream side of a pool that narrows to a chute (transitions to fast-flowing, low turbulence).
*Embayment* - A small, shallow body of water, associated with tributaries or outfalls, that is separated from the main channel and provides backwater habitat areas (little or no current).
*River Remnants* - Meanders that were part of the historical river but are now essentially isolated from the main channel, with discharges substantially lower and less variable than the main channel.
*Tributary Mouths* - The point at which a permanent or ephemeral stream empties into the main stem of the river.

**Identification of Fish Species Guilds Characteristic of Each Habitat Category**. Fish guild composition *for each habitat category* was determined through an interagency effort (Delphi) among ERDC, Fort Worth District, SARA, USFWS, TPWD, and TCEQ. The preliminary guilds were provided by ERDC based on their recent sampling. Both native and non-native species collected were listed in order of relative abundance for each of 8 habitats in the San Antonio River. Guilds were provided to each member of the Delphi group for input on the exclusion of non-native (non-representative) species obtained in sampling, and/or addition of representative species not obtained in samples but known to historically occur in the river.

Participating agencies suggested the addition of several species characteristic of the San Antonio River, including tadpole madtom and Texas logperch. SARA suggested the addition of several species documented from its monitoring program, including spotted gar, gizzard shad, gray redhorse, spotted bass, and smallmouth bass. TCEQ suggested the addition of speckled chub and Guadalupe bass. USFWS and TCEQ advocated the elimination of non-native species, including all tropical livebearers and Mexican tetra, cichlids, and armored catfishes. TCEQ also advocated elimination of sailfin molly contending that it too is non-native. Sailfin molly, a North American species, is native to western Gulf drainages and is listed in some sources as a native of the upper San Antonio River, but some older literature suggests that it is an introduced species.

Table 3-15 displays the final list of fish in each guild, and include all native fish collected by ERDC and all species identified for inclusion by any other participating agency. Species known to be non-native, or suspected to be non-native were excluded.

For each habitat category, HSI values were assigned to ranges of each physical variable that best described suitability for the fish guild that predominated in that habitat during the 2002-2003 surveys. Chutes and riffles were evaluated for swift water species. Embayments, pools, and scour pools were evaluated for slack water species. Old river bendways, tributaries, and chutes below pools were evaluated for both guilds since swift and slack water species co-dominated in those habitats. The red shiner (*Cyprinella lutrensis*), morphologically adapted for swift water, was ubiquitous and numerically dominant at most habitats, and was not considered when describing fish assemblages of habitats as either swift or slack water.

The initial suitability index (SI) values represented a starting point for discussion and revision based on input from participating agencies: SARA, TPWD, TCEQ, USFWS, ERDC, and the Fort Worth District. Preliminary SI values were developed from best professional judgment and supplemented with zoogeographic information and field survey data collected in 2002-2003.

**Prediction of Habitat Variables for Each Habitat Category**. Delineation of pools, riffles, chutes, chutes below pool, and scour pools was accomplished using output from the HEC-RAS existing condition hydraulic model run at the 20 cfs baseflow condition. Outputs provided for each river station from the model included: velocity, depth, water surface

**Table 3-15**
**Habitat Based Fish Guilds**

| | | | |
|---|---|---|---|
| **Old River Bendway** | Central stoneroller<br>Red shiner<br>Blacktail shiner | Texas shiner<br>Yellow bullhead<br>Western mosquitofish | Longear sunfish<br>Largemouth bass |
| **Chute** | Spotted gar<br>Central stoneroller<br>Red shiner<br>Speckled chub<br>Texas shiner | Ghost shiner<br>Weed shiner<br>Mimic shiner<br>Gray redhorse<br>Yellow bullhead | Channel catfish<br>Tadpole madtom<br>Texas logperch |
| **Chute Below Pool** | Red shiner<br>Blacktail shiner<br>Speckled chub<br>Texas shiner<br>Ghost shiner | Weed shiner<br>Mimic shiner<br>Gray redhorse<br>Yellow bullhead<br>Tadpole madtom | Western mosquitofish<br>Largemouth bass<br>Guadalupe bass<br>Green sunfish<br>Texas logperch |
| **Embayment** | Central stoneroller<br>Red shiner<br>Mimic shiner<br>Bullhead minnow<br>Fathead minnow | Yellow bullhead<br>Black bullhead<br>Tadpole madtom<br>Sailfin molly<br>Western mosquitofish | Green sunfish<br>Bluegill<br>Longear sunfish<br>Redspotted sunfish |
| **Pool** | Spotted gar<br>Gizzard shad<br>Central stoneroller<br>Red shiner<br>Texas shiner<br>Ghost shiner<br>Weed shiner<br>Mimic shiner | Fathead minnow<br>Yellow bullhead<br>Black bullhead<br>Channel catfish<br>Tadpole madtom<br>Sailfin molly<br>Western mosquitofish<br>Largemouth bass | Guadalupe bass<br>Green sunfish<br>Bluegill<br>Longear sunfish<br>Redspotted sunfish |
| **Riffle** | Central stoneroller<br>Red shiner | Speckled chub<br>Channel catfish | Orangethroat darter<br>Texas logperch |
| **Scour Pool** | Gizzard shad<br>Central stoneroller<br>Red shiner<br>Texas shiner<br>Weed shiner | Gray redhorse<br>Sailfin molly<br>Western mosquitofish<br>Largemouth bass<br>Guadalupe bass | Warmouth<br>Bluegill<br>Longear sunfish |
| **Tributary** | Spotted gar<br>Gizzard shad<br>Central stoneroller<br>Red shiner<br>Ghost shiner | Weed shiner<br>Gray redhorse<br>Western mosquitofish<br>Largemouth bass | Warmouth<br>Bluegill |

elevation, cumulative surface acres, and water flow width. Five key variables influence the suitability for fish habitat, and were used to establish the HSI model. These were *water depth*, *water velocity*, *dominant substrate*, *vegetation cover*, and *riparian organic input*. Each is briefly described below. Appendix D contains the input data used to determine each habitat variable.

**Water Depth and Water Velocity**. Water depth and velocity are two key components defining the habitats required by various guilds of fishes. A diverse range of water depths and velocities are required to meet the various life cycle stages (foraging, resting, over-wintering, breeding/spawning, nursery, etc.) of aquatic organisms. Optimal pool habitats for fish guilds were defined by ERDC as having depths ranging from 80-100 centimeters (cm), and velocities of 0-10 centimeters per second (cm/s). Optimal riffle habitats were defined as having depths between 18-22 cm, and velocities of 40-60 cm/s. Optimal chute habitats were defined as having depth ranging from 55-65 cm, and velocities of 40-60 cm/s. Backwater habitats (tributary mouths, embayments, restored remnants), are shallow with slow velocities. Water depth and velocity were outputs of the hydraulic model (HEC-RAS) of the without- and with-project condition.

**Dominant Substrate**. Dominant substrate is an important variable for certain life cycle stages (reproduction, foraging) of aquatic organisms, and is particularly important for establishment of lower trophic levels within the community. Sand and fine gravel provide the most desirable or necessary substrate classes within a riverine system. For without-project conditions, substrate was determined visually and classified according to a modified Wentworth-style system of classification as shown in Table 3-16. Dominant substrates were identified for all sites sampled based on maximum observed frequency of that substrate type in 10-point cross-sectional transects. Substrate data for sites not sampled were presumed based on prevalence of substrates in that habitat category at other locations and in proximate reaches.

**Table 3-16**
**Dominant Substrate Characteristics**

| Category | Description | Particle Size (mm) |
|---|---|---|
| 1 | Fines (mud, silt, clay, etc.) | < 0.1 |
| 2 | Sand | 0.1 – 2 |
| 3 | Fine gravel | 2-10 |
| 4 | Coarse gravel | 10-64 |
| 5 | Cobble | 64-128 |
| 6 | Rubble | 128-256 |
| 7 | Boulder | > 256 |

For the with-project condition, a process was developed to determine the sediment particle size that would be dominant by reach based on sediment transport continuity within the river system. The dominant particle size was determined for a given hydraulic condition at every computation point along the river and averaged based on the hydraulic reach being evaluated. Because sedimentation occurs during the latter part of the falling limb of a flood event hydrograph, it was determined that using a discharge equivalent to 10 percent of the peak "Effective Discharge" would be appropriate for determining dominant substrates. Each hydraulic reach was classified for dominant substrate by the average dominant particle size within the hydraulic reach ranging from sands to boulders. The process developed is described below:

- Using the hydraulic model for each plan (DC1, DC2, etc.) and the effective discharges from the Geomorphic Sediment Transport Technical Memorandum (GSTTM), output the average channel bed shear stress.

- Using the Shields Equation, substitute the average channel bed shear stress from the hydraulic model at each cross section for the critical shear stress variable in the equation to solve for the critical particle size. The Shields Equation describes the hydraulic condition at which motion of individual sediment particles may be initiated. This incipient motion can be described as the critical shear stress of the bed material.

- Using the critical or dominant particle size from the equation at each cross section, determine the average dominant particle size for each hydraulic reach (pool, chute, riffle, etc.)

- Using the average particle size for each hydraulic reach, determine the substrate classification (sands, gravels, cobbles, etc.) for each hydraulic reach.

Dominant sediment size was output from the HEC-RAS model. Using the river stations as a common field the previously delineated habitats were overlain on the sediment data. The sediment sizes were then averaged by habitat to represent the dominant substrate variable for each habitat.

**Vegetative Cover**. The effect of shade on aquatic habitats was provided as a variable based on percentage of surface coverage within the channel (e.g., near shore shading). Estimates of vegetative cover for the without- and with-project conditions were completed based on aerial photography, and utilizing Global Information Systems (GIS) technology. A graphical representation was utilized to determine what vegetation types were adjacent to the water for each habitat at each river station. The SI was based on percent cover provided by various vegetation types (i.e. 0.0 percent cover for mowed grassland, 95 percent cover for mature riparian).

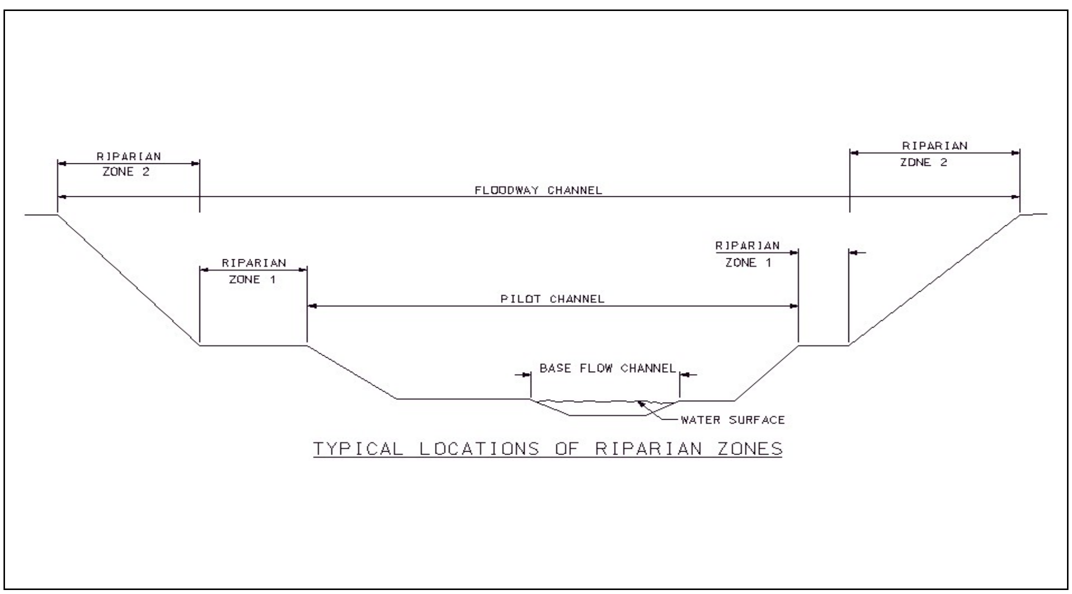
**Riparian Organic Input**. Stream ecologists have recognized the strong dependence of streams on the surrounding riparian environment. The riparian zone bordering streams serves as a buffer between the stream and the surrounding watershed and is also the primary source of organic matter (Harding et al. 1998). There are numerous allocthonous benefits provided to the aquatic habitat by the riparian zone. Allochthonous inputs (leaves, small woody debris, and detritus) are transported into the channel by high water as well as wind from adjacent riparian zones. These and larger materials will be transported downstream by water movement. Organic input from aeolian forces during low water, cumulative effects of input downstream during all river stages, but especially during spates, will provide important benefits to aquatic communities. These include coarse particulate organic matter as food for invertebrate shredders, litter as refugia for benthic fishes like madtoms, and large woody debris as egg-laying sites for crevice-spawning shiners.

The organic input model was developed specifically for this project by the District and ERDC with concurrence from USFWS, TPWD, and TCEQ. The model does not capture the full range of benefits the riparian area provides to the aquatic habitat. In fact, the model only captures one benefit, the input of organic material during inundation. It was recognized by all participants that the model was not the best prediction of the riparian contribution, but has been accepted as a conservative estimate by the group.

In order to quantify organic input to the aquatic habitat associated with the riparian corridor, vegetation plans were subdivided into riparian zone 1 and riparian zone 2 (Figure 3-10). Characteristics of these subdivisions are:

- Riparian Zone 1 vegetation
    - Closest to the channel
    - Occurs primarily in bottom of the floodway
    - Shades the water *and* provides greatest organic input to aquatic habitats
- Riparian Zone 2 vegetation
    - Beyond Riparian Zone 1 vegetation, but within existing floodway.
    - Occurs primarily on the channel side slopes
    - Provides lesser amount of organic input to aquatic habitats

**Figure 3-10**
**Schematic of Riparian Zone 1 and Riparian Zone 2 Locations**



This delineation of the riparian corridor into riparian zone one and two was performed solely for the purpose of quantifying benefits to the aquatic environment based upon inundation frequency, and should not be interpreted as meaning that, as riparian habitat, one zone is more important than the other.

Benefits of vegetation as organic input are delineated based upon type, proximity to shore, and flood frequency (although most benefits of the riparian contribution are not tied to the frequency of inundation (Stream Ecology. 2004. Heterotrophic Energy Sources and Decomposition)). The SI for the organic input variable associated with each individual channel feature (e.g., pool, riffle, chute, etc.) was calculated as:

$$\mathbf{SI}_{\text{Organic Input}} = \frac{\mathbf{K}[\ \Sigma\ (\mathbf{SI})(\%\mathbf{Area})\ ]_{\text{Riparian Zone 1}} + [\ \Sigma\ (\mathbf{SI})(\%\ \mathbf{Area})\ ]_{\text{Riparian Zone 2}}}{\mathbf{K+1}}$$

K is a constant (i.e., a ratio) expressing the relative frequency of inundation of riparian zone one (the elevated flat immediately adjacent to the baseflow channel) and riparian zone two (the landward slope adjacent to riparian zone one). For example, if riparian zone one is inundated 100 days and riparian zone two only 20 of those days, this constant will equal five. For each riparian zone, the percentage area of each vegetative type is multiplied times the SI for that type, and all values are summed. All categories of vegetation therefore contribute to the HSI, but are weighted proportionately based on frequency of inundation and their respective relative areas.

Vegetation identified for the without- and with-project conditions was captured using ArcMap 8.3, a geospatial analysis tool. Using ArcMap, the longitudinal limits of each pool, riffle, chute, and scour pool (pilot channel components) were used as bisection points for determining the vegetation associated laterally with each of these habitat features. The vegetation was further bisected longitudinally into zones of riparian zone one and riparian zone two. This procedure allowed calculation of the zone one and zone two vegetation acreages associated with a particular aquatic habitat.

**Aquatic Habitat Suitability Index Calculations.** Once the value of the five habitat variables were established for a design condition, SI values for each variable were assigned. For each site, a SI value was determined for each variable on a scale of 0.0 (unsuitable) to 1.0 (optimal) based on habitat suitability models developed for the specific habitat type and its associated guild. For velocity, depth, and vegetative cover (continuous variables) SIs, intermediate values not specified were interpolated assuming a linear relationship between any two points For example, a predicted water velocity of 28 cm/s would score an SI value of 0.88, if suitability index models indicated SIs of 0.8 for 20 cm/s and 1.0 for 40 cm/s). The HSI for each habitat was calculated using a geometric mean formula:

$$\mathbf{HSI} = [(\mathbf{SI}_{\text{Velocity}})(\mathbf{SI}_{\text{Depth}})(\mathbf{SI}_{\text{Substrate}})(\mathbf{SI}_{\text{Veg Cover}})(\mathbf{SI}_{\text{Organic Input}})]^{1/5}$$

Use of a geometric mean allows variables with the lowest SI values to be moderately compensated by variables with higher SI values. Habitat units were calculated for each site (e.g., a point in a pool), compiled for each individual habitat feature (e.g., a single pool), and summarized for each category (e.g., all pools). The maximum HU per acre is 1.0.

HUs are converted to average annual habitat units (AAHUs) using a 50-year period of analysis and annualization formula and the acres determined for each habitat. Appendix D contains the complete data input for delineating aquatic habitats and developing HSI, and computing HU including acres, geometric mean, and computed HU each type of individual aquatic habitat for a 50-year period under without project conditions.

**Evaluation of Riparian Habitat**. For south-central Texas, the wooded uplands, prairie uplands, and riparian corridors work in unison to provide the habitat needs for many species of wildlife that call this unique part of Texas home. Upland areas in this part of the state are mostly prairie with some woodland consisting of legumes and other small and/or short-lived species. These wooded uplands do not typically progress along an ecological pathway to late sucessional woodlands because the climate of the area is not favorable for late sucessional species except where associated with riparian corridors. Therefore, many species of birds and other wildlife, which occupy upland habitats exclusively in other areas of the U.S., occupy the riparian areas of south-central Texas exclusively or in conjunction with the upland habitats. For many species, the riparian areas of south-central Texas are needed to meet the needs of their circadian and circannual rhythms. However, riparian areas of the region are small and less diverse than their northeastern counterparts; therefore, connection to upland woodlands is also important to provide the full range of habitat requirements of a species. Additionally, due to fragmentation of upland habitats, a riparian corridor serves as the only travel conduit for species to emigrate to other habitats needed to complete their life requisites.

A review of the exclusive riparian/aquatic models available revealed that while these models could be used to measure improvements to existing riparian habitat for a particular species, they were not capable of capturing the more intricate details associated with building a riparian corridor from the degraded condition of the study area. It was clear that quantifying the benefits of restoring a riparian corridor from scratch meant capturing the benefits along the entire sucessional continuum, from seedlings to saplings, to mature trees, and for Type A vegetation, the succession in under story density and the gradual change in canopy structure, density, and species. Each of these sucessional stages provides quality and necessary habitat for species that are not readily available in the upland habitats.

The USFWS, with assistance from the TPWD and the Fort Worth District, completed a habitat evaluation of the without- (existing and future) and with-project condition of riparian natural resources based on their value as wildlife and avian habitat. Because the resource agencies are most concerned in the restoration of the aquatic and riparian habitat functions lost when the flood control channel was constructed, the focus was to use models containing variables measuring important components of riparian corridor structure. A review of the available models providing the variables necessary to build quality riparian habitat was undertaken. The final array of HSI models for the HEP evaluation included raccoon, fox squirrel, and barred owl. Additionally, the shelterbelt HSI model was modified to represent a natural riparian woodland, and captures the benefits of lower vegetation strata within riparian woodlands important to a number of species.

The barred owl occupies various habitats in other parts of its range, but in south-central Texas the barred owl is exclusive to riparian corridors. The barred owl also represents the guild of carnivores. Building habitat that performs well for the barred owl means it also performs well for prey species requiring a riparian vegetation structure. Other species of carnivorous birds using riparian corridors in the San Antonio region include the sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk (*Buteo lineatus*), and broad-winged hawk (*Buteo playpterus*). As a note on significance, all North American diurnal birds of prey, except bald and golden eagles, are listed as migratory birds, and therefore, protected under the U.S. Migratory Bird Treaty Act. Other predatory wildlife species benefiting from building habitat conducive to small mammals in a riparian woodland include, but not limited to the checkered garter snake (*Thamnophis marcianus marcianus*), redstripe ribbon snake (*Thamnophis proximus rubrilineatus*), eastern garter snake (*Thamnophis sirtalis sirtalis*), red fox (*Vulpes vulpes*), mink (*Mustela vison*), and long-tailed weasel (*Mustela frenata*).

A species may adapt to an unnatural environment, but it does not necessarily thrive in that environment. Species forced to adapt to habitats unlike those it historically occupied are not true representatives of the species. Restoration should look to provide the necessary components of a species natural habitat in an effort to conserve the historical and true ecological nature and context of the species and its environment. The raccoon, while urban and upland adaptable, has a clear preference for perennial streams with well-developed riparian vegetation. Like many of the species of south central Texas the raccoon can only find many of the components necessary to its preferred habitat in the riparian corridors of the region. The raccoon is sometimes classified as a carnivore, but it is definitely opportunistic and assumes omnivore tendencies at certain times of the year. Restoration components providing quality habitat for raccoons will also benefit other omnivore, herbivores, and carnivore species including many that have already been mentioned.

The fox squirrel was chosen because it represented a species requiring woodlands with a mature structure -- large trees and limited understory. Additionally, the fox squirrel serves to represent the herbivore guild. Restoration providing the proper vegetation structure for fox squirrels will also provide the proper structure for other species requiring similar riparian corridor components as a part of their necessary habitat. These species include, but are not limited to Mexican ground squirrel (*Spermophilus mexicanus*), white-tailed deer (*Odocoileus virginianus*), red-headed woodpecker (*Melanerpes erythrocephalus*), red-bellied woodpecker (*Melanerpes carolinus*), and yellow-bellied sapsucker (*Sphyrapicus varius*).

Most HEP models were developed with the idea that the area of evaluation will be "left to nature" once modifications are complete. This is not true for the study area given it also serves as a flood control channel. A shortcoming of the barred owl, raccoon, and fox squirrel models is they are driven by large trees, and did not include a variable for the understory or midstory components of woodlands. In a "left to nature" environment, the understory and midstory would develop naturally along with the trees. However, due to the high hydraulic resistance of understory shrubs and midstory trees, these horizontal layers of the riparian woodlands were absent in two of the three wooded vegetation types under consideration (Type C and D). Additionally, because these models are driven by tree size, Type C and D are unrealistically favored over the more natural Type A vegetation. Still, the three models were capturing other important riparian structure components. The shelterbelt model was adapted to represent natural riparian woodland to offset the unnatural bias towards large trees. The modified shelterbelt model captures the benefits of lower vegetation strata within riparian woodlands important to a number of species. These include many neotropical birds, riparian related amphibians, and small mammals.

A reference site was selected to test the model's usefulness as a guide and prediction mechanism for restoring the riparian corridor to a more natural condition. Immediately downstream of the project area is a relatively undisturbed riparian corridor with large trees and appropriately dense mid- and under-story vegetation for late sucessional riparian woodland. The resource agencies felt this site represented an area of high quality riparian habitat, and should be the type of habitat the restoration should be attempting to create for the study area. Using a sample plot within this reference site to test the model, a HEP accounting was performed using the species variables selected. The model concluded the reference site to be of optimal quality (HSI = 1) leading to the conclusion that the models are good prediction mechanism for estimating the benefits of riparian habitat restoration.

Variables for individual species were used to calculate values of specific life requisites (e.g. food, water, cover, and reproduction.) A summary of the variables for the HSI models used in this analysis is provided in Table 3-17.

Cover types surveyed within the existing project right-of-way were dominated by mowed grassland, dry channel, tributary, and hard, non-vegetated surfaces. Other cover types surveyed both within and outside the project ROW (within areas considered for acquisition) include, late successional woodland, legume woodland, mid successional woodland, and woodland. One reference site was surveyed downstream of the floodway as a basis for comparison with other sites. The HSI for each existing and proposed future cover type (without- and with-project) was calculated by averaging each of the species HSI models as:

$$\mathbf{HSI}_{\text{Average}} = \frac{\mathbf{HSI}_{\text{Raccoon}} + \mathbf{HSI}_{\text{Fox Squirrel}} + \mathbf{HSI}_{\text{Barred Owl}} + \mathbf{HSI}_{\text{Shelterbelt}}}{4}$$

**Table 3-17**
**Summary of Variables for Riparian Habitat Suitability Index Models**

| HSI Model used for HEP | Summary of Variables | Life Requisites |
|---|---|---|
| Raccoon | V1=Distance to water<br>V2=Water regime<br>V3=Overstory forest size<br>V4=Refuge sites per acre | 1. Water<br>2. Cover/reproduction |
| Fox squirrel | V1=Percent canopy closure of trees that produce hard mast ≥10 inch dbh<br>V2=Distance to available grain<br>V3= Average dbh of overstory trees<br>V4=Percent tree canopy closure<br>V5=Percent shrub crown cover | 1. Winter food<br>2. Cover/reproduction |
| Barred owl | V1=Number of trees ≥20 inch dbh/acre<br>V2=Mean dbh of overstory trees<br>V3=Canopy cover of overstory trees | 1. Reproduction |
| Shelterbelt* | V1=Average height of 2 tallest vegetation rows<br>V4=Number of woody plant species<br>V5=Configuration of woody plant species | N/A - This model provides an index of species richness. |

*Note: Shelterbelt HSI model was modified by USFWS specifically for this project. Variable 2 (percent canopy closure), Variable 3 (number of shelterbelt rows), and Variable 6 (patch size) were not used for this study.
dbh=diameter at breast heigh

## RESULTS OF HABITAT EVALUATION

Under without project conditions, the San Antonio River within the study area has 61.77 aquatic acres (not including the 7.46 acres of dry channel identified in table 3-2) providing 26.7 habitat units, indicating poor habitat suitability. The average annual habitat units reflect the degraded nature of the San Antonio River for all guilds of fishes. Of the 61.77 acres of defined aquatic habitat within the San Antonio River in the study area, the habitat is dominated by pool (39.37 acres or 64%) and chute (19.34 acres or 31%) habitats. The remaining riffle, embayment, tributary mouth, chute below pool, and scour pool comprise the remaining 3.06 acres (5%). These proportions indicate a relatively low diversity of habitats.

Habitat quality, measured by the five aquatic variables (suitability indexes) previously described varied among the aquatic habitat types. For pools, weighted average suitability indices of 0.10 for organic input, 0.28 for dominant substrate, and 0.49 for vegetative cover were the leading factors in a low habitat suitability index. The absence of vegetation (for organic input and cover) and the presence of large substrates (inefficient sediment transport) resulted in a habitat suitability index of ranging between 0.29 and 0.42 for individual pools computed using a geometric mean. Consequently the computed average annual habitat units of 15.8 represents only 40-percent of the potential maximum habitat carrying capacity.

For chutes, weighted average suitability indexes of 0.10 for organic input (absence of vegetation) is the major restrictive factor in habitat quality. The resultant habitat suitability index for individual chutes ranges between 0.37 and 0.54, and an average annual habitat unit of 9.6 or 49% of the potential maximum habitat carrying capacity.

For riffles, weighted average suitability indices of 0.38 for water depth (too shallow), 0.54 for dominant substrates (too large), and 0.10 for organic input (absence of vegetation) prohibit this habitat type from reaching its full potential. The resultant habitat suitability index for individual riffles ranges between 0.36 and 0.5, and an average annual habitat unit of 0.52 or 41% of the potential maximum habitat carrying capacity.

The habitat quality of the remaining aquatic habitat types is depressed from the absence of vegetation. In addition, chutes below pools are too shallow, and scour pools have a too large of a dominant substrate. Regardless, there relatively small acreage practically provides very little habitat value.

Table 3-18 displays a weighted average summary of the suitability indexes for the five aquatic variables along with the acres and average annual habitat units for the aquatic habitat under the without project condition. Appendix D.2 contains the complete data and analysis of the suitability indices, habitat suitability indices, and habitat units.

Results of baseline analysis indicate that changes in water velocity are not required for substantial gains in habitat value. Suitability is limited principally by the low availability of smaller substrates (fines, sand, and fine gravel) and riparian vegetation, and to a lower degree, deeper water (> 40 cm). Substantial gains in extant habitats can be realized by removing large, unnatural substrates, re-vegetating the riparian corridor, and by creating (or connecting) off-channel habitats (embayments, tributary mouths, old channel bendways) (Hoover et al. 2004).

**Table 3-18**
**Weighted Average Summary of**
**Suitability Indexes and Average Annual Habitat Units**
**Without Project Aquatic Habitat**

| | SUITABILITY INDEX | | | | | | |
|---|---|---|---|---|---|---|---|
| Aquatic Habitat / (# of occurrences) | Water Velocity | Water Depth | Organic Input | Dominant Substrate | Vegetation Cover | Total Acres | Average Annual Habitat Units |
| Pool (22) | 0.93 | 0.77 | 0.10 | 0.28 | 0.49 | 39.37 | 15.8 |
| Chute (21) | 0.93 | 0.64 | 0.10 | 0.79 | 0.70 | 19.34 | 9.6 |
| Riffle (6) | 0.89 | 0.38 | 0.10 | 0.54 | 0.70 | 1.26 | 0.52 |
| Embayment (1) | 1.00 | 0.92 | 0.10 | 0.80 | 0.45 | 0.01 | 0.01 |
| Tributary Mouth (1) | 0.85 | 0.97 | 0.10 | 1.00 | 0.70 | 0.17 | 0.10 |
| Chute below pool (8) | 0.73 | 0.24 | 0.12 | 0.65 | 0.86 | 0.37 | 0.12 |
| Scour Pool (1) | 0.98 | 0.83 | 0.10 | 0.40 | 0.50 | 1.25 | 0.55 |

Table 3-19 displays the habitat suitability index (HSIs), acres, and habitat unit (HUs) for the various riparian cover types (habitats) within the Mission Reach at years 1-, 5-, 15-, 25-, and 50 (showing existing and future without project conditions), as determined by the USFWS. Riparian woodland habitat was assessed at 27 sample sites along the San Antonio River. Vegetative cover types delineated (by the USFWS) include non-native grasslands, legume woodlands, parklands, and industrial. HSIs for these cover types were scaled in relation to native riparian woodland. Acres of rubble and storm water outfalls (non-vegetated surfaces) were also captured due to the potential to provide post-project ecosystem benefits from restoration measures applied to these features. Habitat suitability within the Mission Reach ranges from 0.0 (mowed Bermuda) to 0.96 (late successional woodland). The absence of shrubs and trees in the floodway limits its suitability for all woodland species, therefore, grasslands were assigned an HSI of 0.0 by the USFWS. The woodland site with the highest overall score was the reference site downstream of the SACIP (Site 27). Upstream from Site 27, the remaining woodlands appear to have been disturbed to some degree by logging and/or fires.

The results presented in Table 3-19 indicate there is enormous potential to increase the quality of the terrestrial habitat throughout the project area. There is a total of 300.55 acres of non-native grassland in the Mission Reach, most occurring in or near the floodway channel. These grasslands represent a loss of natural riparian woodlands. Non-vegetated surfaces (concrete or concrete rubble) along the banks of the baseflow channel account for 24.32 acres of the Mission Reach study area. These non-vegetated areas have no habitat benefits (0.0 HUs), and represent a loss of acreage for streamside vegetation and soil to water interface.

All of the woodlands are found in the overbank areas of the flood control channel and represent a diverse mixture of successional stages. The predominate woodland type is legume thicket woodland. The HSI values for this woodland type range from 0.15 for an early successional stand to 0.48 for a mid-successional stand and are indicative of the degraded nature of many of the woodlands due to invasion by exotic species such as privot and Chinaberry. The full USFWS report and photos is available in Appendix J.

**Table 3-19**
**Without Project Riparian Habitat Suitability Indices (HSI) and Habitat Units (HU)**

| | Existing Condition | | | Future Without Project | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cover type** | **Acres** | **HSI** | **HU** | **Acres** | ***Year 01*** | | ***Year 05*** | | ***Year 15*** | | ***Year 25*** | | ***Year 50*** | |
| | | | | | ***HSI*** | ***HU*** | ***HSI*** | ***HU*** | ***HSI*** | ***HU*** | ***HSI*** | ***HU*** | ***HSI*** | ***HU*** |
| Non-native grassland | 308.84 | 0.00 | 0.00 | 308.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Legume woodland | 46.95 | .037 | 17.37 | 46.95 | 0.37 | 17.37 | 0.36 | 16.90 | 0.35 | 16.43 | 0.33 | 15.49 | 0.30 | 14.09 |
| Late successional woodland | 0.02 | 0.96 | 0.02 | 0.02 | 0.96 | 0.02 | 0.96 | 0.02 | 0.96 | 0.02 | 0.96 | 0.02 | 0.96 | 0.02 |
| Mid successional woodland | 0.91 | 0.48 | .044 | 0.91 | 0.48 | 0.44 | 0.48 | 0.44 | 0.50 | 0.46 | 0.53 | 0.48 | 0.58 | 0.53 |
| Park woodland | 10.65 | 0.34 | 3.62 | 10.65 | 0.34 | 3.62 | 0.34 | 3.62 | 0.34 | 3.62 | 0.34 | 3.62 | 0.34 | 3.62 |
| Woodland | 26.84 | 0.37 | 9.93 | 26.84 | 0.37 | 9.93 | 0.36 | 9.66 | 0.35 | 9.39 | 0.33 | 8.86 | 0.30 | 8.05 |
| Non-vegetated surfaces | 24.32 | 0.00 | 0.00 | 24.32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Totals for Mission Reach** | **418.53** | | **30.98** | **418.53** | | **30.98** | | **30.64** | | **29.92** | | **28.47** | | **26.31** |

## FUTURE WITHOUT PROJECT CONDITION

Stability is defined as a condition where the channel retains its cross sectional geometry and energy grade without excessive erosion or deposition on an engineering time scale (25-50 year time horizon). Stability is affected by the sediment supply to the system and the hydraulic forces that determine its sediment transport capacity. Studies conducted on the Mission Reach indicate that the SACIP has some inherent instability concerns. A highly erosive environment, particularly downstream of the confluence with San Pedro Creek, has been confirmed while Davis Lake acts as a downstream control, as discussed in the historical channel assessment. The future without-project condition of the Mission Reach would be a continued degradation of the SACIP through channel erosion. As urbanization affects future hydrology and sediment load to the system, it is anticipated that stresses to the current system will increase.

The future, without-project condition for aquatic and riparian habitat is projected from existing HSI values, and based on best available scientific information. Variables influencing the future without project condition were discussed and agreed upon by the many agencies participating in this study including SARA, USACE, ERDC, USFWS, and TPWD. For riparian habitat, factors considered were the continued mowing of floodway grasslands; the gradual maturation of trees in the woodland patches; and continued expansion of dense privet (*Ligustrum spp.)* mottes in the riparian corridor. Land use was assumed to continue unchanged in part due to local flood ordinances. The future without-project condition would be similar to today's condition. The characteristics of the floodway vegetation would remain essentially unchanged, except perhaps for shifts in population composition. In order to maintain the current level of flood protection, the floodway would have to remain a highly maintained area. No encroachment of vegetation (native or otherwise) would be permitted. Shifts in both aquatic and terrestrial population composition would likely continue through the establishment of invasive species, or natives tolerant of disturbed conditions. The USFWS predicts a slight decrease in overall riparian HUs over a 50-year period for the Mission Reach under the without-project condition. Because the floodway within the Mission Reach is regularly maintained and is a managed environment, ERDC has determined that there would be no change to the aquatic habitat over the next 50-year period.

## EVALUATION OF DESIGN CONDITIONS AND COMPARISON TO WITHOUT PROJECT CONDITION

All alternatives considered represent combinations of the three component measures previously discussed. Specifically, all combinations of design conditions and measures are developed within the following framework:

*Channel Modification.* Design Condition 0, 1, 2, or 3.

*Vegetation.* Includes either riparian zone one *or* riparian zone one and two. The distribution of vegetation Types A, C, D, or E will be different for each design condition, as the differences in the hydraulic pallet will allow differing densities of vegetation to be introduced before the hydraulic performance constraint is violated.

*Special Aquatic Measures.* The number, type, and location of special aquatic measures associated with a specific DC based on differences in each DC's hydraulic pallet.

**Aquatic Habitat Outputs**. Aquatic habitat outputs under each design condition (DC) are computed in the same manner as the without project condition using the process previously described**.** The five variables used to compute the aquatic HSIs for the design conditions are velocity, depth, dominant substrate, percent vegetative cover, and riparian organic input for individual pool, riffle, chute, embayment, tributary mouth, and restored remnants.

A comparison of the weighted average SI values by analysis years for each aquatic habitat type under the without project condition and each DC is presented in Tables 3-20 through 3-23. Values for each individual habitat contained in a DC is located in Appendix D.

DC1 increases the amount of aquatic habitat by 38.54 acres over the without project condition. Pools, riffles, and chutes comprise 87-percent of the aquatic habitat. For DC1 (Table 3-20) when compared to the without project condition suitability indices Table 3-18, organic input (vegetation) increase from 0.1 (without project condition) to 0.48 for pools, 0.41 for chutes, 0.42 for riffles, 0.60 for embayments, 0.4 for tributary mouths, and 1.0 for river remnants. These represent increases of between 400- and 900-percent. Dominant substrate increases from 0.28 (without project condition) for pools to 0.8, an increase of 185-percent. All other suitability indices also experience increases under this DC.

DC2 increases the amount of aquatic habitat by 36.69 acres over the without project condition. Pools, riffles, and chutes comprise 87-percent of the aquatic habitat. For DC2 (Table 3-21) when compared to the without project condition suitability indices Table 3-18, organic input (vegetation) increase from 0.1 (without project condition) to 0.54 for pools, 0.52 for chutes, 0.56 for rifles, 0.82 for embayments, 0.42 for tributary mouths, and 1.00 for river remnants. These represent increases of between 400- and 900-percent. Dominant substrate increases from 0.28 (without project condition) for pools to 0.75, an increase of 142-percent. All other suitability indices also experience increases under this DC.

DC3A increases the amount of aquatic habitat by 30.86 acre over the without project condition. Pools, riffles, and chutes comprise 84-percent of the aquatic habitat. For DC3A (Table 3-22) when compared to the without project condition suitability indices Table 3-18, organic input (vegetation) increase from 0.1 (without project condition) to 0.57 for pools, 0.58 for chutes, 0.56 for rifles, 0.72 for embayments, 0.48 for tributary mouths, and 0.6 for river remnants. These represent increases of between 400- and 600-percent. Dominant substrate increases from 0.28 (without project condition) for pools to 0.68, an increase of 142-percent. All other suitability indices also experience increases under this DC.

DC3B increases the amount of aquatic habitat by 44.17 acres over the without project condition. Pools, riffles, and chutes comprise 85-percent of the aquatic habitat. For DC3B (Table 3-23) when compared to the without project condition suitability indices (Table 3-18), organic input (vegetation) increase from 0.1 (without project condition) to 1.0 for pools, 1.0 for chutes, 0.51 for rifles, 0.76 for embayments, 0.61 for tributary mouths, and 0.86 for river remnants. These represent increases of between 400- and 900-percent. Dominant substrate increases from 0.28 (without project condition) for pools to 1.0, an increase of 257-percent. All other suitability indices also experience increases under this DC.

It is clear each DC significantly improves the quantity of aquatic habitat, and the increases the habitat suitability indices (quality of habitat). Table 3-24 provides an additional comparison of the average annual habitat units (AAHUs) for each aquatic habitat type for each DC. This increase is the result of increases in both the amount of habitat acreages and increases in suitability indices. In summary, DC1 increases aquatic habitat AAHUs by 45.85, a 72-percent increase. DC2 increases aquatic habitat AAHUs 43.23, a 162-percent increase. DC3A increases aquatic habitat AAHUs by 39.84, a 149-percent increase, DC3B increases aquatic habitat AAHUs by 50.67, a 190-percent increase. DC3B provides the greatest increase in aquatic habitat acres and AAHU.

**Table 3-20**
**Weighted Average Summary of**
**Suitability Indexes, Habitat Suitability Indexes, and Habitat Units**
**Design Condition One**

| Aquatic Habitat / | WATER VELOCITY period of analysis | | | | | WATER DEPTH period of analysis | | | | | ORGANIC INPUT period of analysis | | | | | DOMINANT SUBSTRATE period of analysis | | | | | VEGETATION COVER period of analysis | | | | | Total | HABITAT UNITS period of analysis | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (# of occurrences) | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | Acres | yr1 | yr5 | yr15 | yr25 | yr50 | Annual |
| Pool | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.09 | 0.23 | 0.42 | 0.46 | 0.48 | 0.70 | 0.80 | 0.80 | 0.80 | 0.80 | 0.50 | 0.55 | 0.61 | 0.65 | 0.75 | 71.93 | 4.44 | 5.68 | 6.44 | 6.52 | 6.69 | 48.34 |
| Chute | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.90 | 0.22 | 0.38 | 0.41 | 0.41 | 0.20 | 0.81 | 0.81 | 0.81 | 0.81 | 0.70 | 0.78 | 0.86 | 0.90 | 0.89 | 16.90 | 0.64 | 1.03 | 1.17 | 1.09 | 1.21 | 11.02 |
| Riffle | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.10 | 0.25 | 0.39 | 0.41 | 0.42 | 0.20 | 0.80 | 0.80 | 0.80 | 0.80 | 0.70 | 0.75 | 0.80 | 0.82 | 0.85 | 4.68 | 0.12 | 0.19 | 0.22 | 0.22 | 0.22 | 2.50 |
| Scour Pool | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.09 | 0.28 | 0.28 | 0.28 | 0.28 | 0.40 | 1.00 | 1.00 | 1.00 | 1.00 | 0.80 | 0.78 | 0.78 | 0.78 | 0.78 | 1.17 | 0.57 | 0.84 | 0.84 | 0.84 | 0.84 | 0.83 |
| Embayments | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.10 | 0.22 | 0.51 | 0.60 | 0.60 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.30 | 0.51 | 0.69 | 0.87 | 0.99 | 5.82 | 0.46 | 0.60 | 0.76 | 0.81 | 0.82 | 4.13 |
| Tributary Mouths | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.07 | 0.16 | 0.32 | 0.40 | 0.40 | 0.66 | 0.91 | 0.91 | 0.91 | 0.91 | 0.50 | 0.53 | 0.58 | 0.66 | 0.78 | 0.46 | 0.12 | 0.15 | 0.18 | 0.19 | 0.21 | 0.16 |
| River Remnants | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.10 | 0.20 | 0.65 | 1.00 | 1.00 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.10 | 0.18 | 0.50 | 0.88 | 1.00 | 0.50 | 0.20 | 0.25 | 0.39 | 0.48 | 0.49 | 0.38 |

**Table 3-21**
**Weighted Average Summary of**
**Suitability Indexes, Habitat Suitability Indexes, and Habitat Units**
**Design Condition Two**

| Aquatic Habitat / | WATER VELOCITY period of analysis | | | | | WATER DEPTH period of analysis | | | | | ORGANIC INPUT period of analysis | | | | | DOMINANT SUBSTRATE period of analysis | | | | | VEGETATION COVER period of analysis | | | | | Total | HABITAT UNITS period of analysis | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (# of occurrences) | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | Acres | yr1 | yr5 | yr15 | yr25 | yr50 | Annual |
| Pool | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.10 | 0.23 | 0.49 | 0.54 | 0.54 | 0.70 | 0.68 | 0.68 | 0.68 | 0.68 | 0.50 | 0.58 | 0.59 | 0.60 | 0.61 | 70.28 | 5.42 | 6.49 | 7.67 | 7.73 | 7.74 | 45.90 |
| Chute | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.10 | 0.25 | 0.46 | 0.52 | 0.52 | 0.20 | 0.93 | 0.93 | 0.93 | 0.93 | 0.70 | 0.84 | 0.87 | 0.89 | 0.88 | 7.72 | 0.51 | 0.87 | 0.99 | 1.02 | 1.02 | 5.57 |
| Chute Below Pool | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.10 | 0.30 | 0.31 | 0.31 | 0.31 | .20 | 0.50 | 0.50 | 0.50 | 0.50 | 0.70 | 0.92 | 0.92 | 0.92 | 0.92 | 0.12 | 0.04 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| Riffle | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.10 | 0.25 | 0.49 | 0.56 | 0.56 | 0.21 | 0.84 | 0.84 | 0.84 | 0.84 | 0.72 | 0.77 | 0.79 | 0.80 | 0.83 | 14.51 | 0.38 | 0.59 | 0.69 | 0.71 | 0.72 | 8.46 |
| Scour Pool | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.10 | 0.23 | 0.53 | 0.67 | 0.67 | 0.40 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 0.79 | 0.79 | 0.79 | 0.79 | 1.51 | 0.66 | 1.03 | 1.21 | 1.27 | 1.27 | 1.19 |
| Embayments | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.10 | 0.22 | 0.58 | 0.82 | 0.82 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.30 | 0.42 | 0.66 | 0.88 | 1.00 | 2.65 | 0.25 | 0.31 | 0.42 | 0.47 | 0.49 | 1.73 |
| Tributary Mouths | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.10 | 0.18 | 0.32 | 0.42 | 0.42 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 0.70 | 0.76 | 0.88 | 0.82 | 0.69 | 0.8 | 0.05 | 0.07 | 0.08 | 0.23 | 0.08 | 0.35 |
| River Remnants | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.10 | 0.20 | 0.65 | 1.00 | 1.00 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.10 | 0.25 | 0.57 | 0.80 | 1.00 | 0.94 | 0.17 | 0.23 | 0.34 | 0.40 | 0.42 | 0.39 |

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**Table 3-22**
**Weighted Average Summary of**
**Suitability Indexes, Habitat Suitability Indexes, and Habitat Units**
**Design Condition Three A**

| | WATER VELOCITY | | | | | WATER DEPTH | | | | | ORGANIC INPUT | | | | | DOMINANT SUBSTRATE | | | | | VEGETATION COVER | | | | | | HABITAT UNITS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquatic Habitat / | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | Total | *period of analysis* | | | | | Average |
| (# of occurrences) | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | Acres | yr1 | yr5 | yr15 | yr25 | yr50 | Annual |
| Pool | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.09 | 0.18 | 0.51 | 0.57 | 0.57 | 0.69 | 0.75 | 075 | 0.75 | 0.75 | 0.50 | 0.55 | 0.62 | 0.67 | 0.75 | 67.79 | 5.26 | 6.18 | 7.79 | 8.06 | 8.40 | 42.88 |
| Chute | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.12 | .019 | 0.54 | 0.57 | 0.58 | 0.20 | 0.83 | 0.83 | 0.83 | 0.83 | 0.70 | 0.77 | 0.77 | 0.77 | 0.77 | 15.80 | 0.39 | 0.61 | 0.68 | 0.68 | 0.76 | 10.87 |
| Riffle | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.09 | 0.19 | 0.55 | 0.56 | 0.56 | 0.20 | 0.80 | 0.80 | 0.80 | 0.80 | 0.70 | 0.74 | 0.84 | 0.92 | 0.89 | 0.28 | 0.08 | 0.00 | 0.00 | 0.00 | 0.16 | 0.15 |
| Scour Pool | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.09 | 0.18 | 0.51 | 0.55 | 0.55 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.50 | 0.56 | 0.56 | 0.56 | 0.56 | 1.53 | 0.65 | 0.76 | 0.95 | 0.96 | 0.96 | 0.91 |
| Embayments | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.10 | 0.20 | 0.58 | 0.58 | 0.72 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.30 | 0.36 | 0.46 | 0.70 | 0.92 | 5.13 | 0.44 | 0.52 | 0.68 | 0.74 | 0.82 | 3.84 |
| Tributary Mouths | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.08 | 0.16 | 0.48 | 0.48 | 0.48 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.70 | 0.76 | 0.84 | 0.89 | 0.95 | 0.88 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.49 |
| River Remnants | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 | 0.10 | 0.20 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.10 | 0.37 | 0.56 | 0.85 | 0.95 | 1.39 | 0.25 | 0.37 | 0.50 | 0.55 | 0.55 | 1.00 |

**Table 3-23**
**Weighted Average Summary of**
**Suitability Indexes, Habitat Suitability Indexes, and Habitat Units**
**Design Condition Three B**

| | WATER VELOCITY | | | | | WATER DEPTH | | | | | ORGANIC INPUT | | | | | DOMINANT SUBSTRATE | | | | | VEGETATION COVER | | | | | | HABITAT UNITS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquatic Habitat / | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | *period of analysis* | | | | | Total | *period of analysis* | | | | | Average |
| (# of occurrences) | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | yr1 | yr5 | yr15 | yr25 | yr50 | Acres | yr1 | yr5 | yr15 | yr25 | yr50 | Annual |
| Pool | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.09 | 0.20 | 0.48 | 0.56 | 0.56 | 0.69 | 0.73 | 0.73 | 0.73 | 0.73 | 0.48 | 0.56 | 0.60 | 0.63 | 0.72 | 68.89 | 4.94 | 5.89 | 7.12 | 7.39 | 7.59 | 46.08 |
| Chute | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.09 | 0.22 | 0.46 | 0.53 | 0.53 | 0.20 | 0.90 | 0.90 | 0.90 | 0.90 | 0.70 | 0.76 | 0.76 | 0.76 | 0.76 | 9.43 | 0.35 | 0.8 | 0.67 | 0.69 | 0.69 | 6.72 |
| Riffle | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.09 | 0.21 | 0.45 | 0.51 | 0.51 | 0.20 | 0.78 | 0.78 | 0.78 | 0.78 | 0.70 | 0.74 | 0.79 | 0.83 | 0.87 | 18.42 | 0.37 | 0.58 | 0.68 | 0.70 | 0.71 | 11.00 |
| Scour Pool | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.78 | 0.78 | 0.78 | 0.78 | 0.78 | 0.08 | 0.14 | 0.45 | 0.52 | 0.52 | 0.40 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 0.52 | 0.54 | 0.55 | 0.60 | 1.55 | 0.64 | 0.91 | 1.11 | 1.14 | 1.16 | 1.08 |
| Embayments | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.10 | 0.20 | 0.57 | 0.76 | 0.76 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.30 | 0.44 | 0.67 | 0.82 | 0.99 | 5.13 | 0.44 | 0.61 | 0.74 | 0.82 | 0.85 | 4.07 |
| Tributary Mouths | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.0 | 0.20 | 0.59 | 0.61 | 0.61 | 0.50 | 0.91 | 0.91 | 0.91 | 0.91 | 0370 | 0.81 | 0.96 | 1.00 | 0.90 | 0..71 | 0.05 | 0.07 | 0.09 | 0.09 | 0.09 | 0.54 |
| River Remnants | 0.87 | 0.87 | 0.87 | 0.87 | 0.87 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.09 | 0.17 | 0.56 | 0.86 | 0.86 | 0.87 | 0.87 | 0.87 | 0.87 | 0.87 | 0.09 | 0.16 | 0.44 | 0.55 | 0.87 | 1.52 | 0.28 | 0.52 | 0.55 | 0.63 | 0.69 | 1.23 |

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**Table 3-24**
**Comparison between Without-Project and Design Conditions Average Annual Habitat Units for Aquatic Measures**

| | Without Project | | DC 1 | | DC 2 | | DC3A | | DC3B | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AAHU | Acres | AAHU | Acres | AAHU | Acres | AAHU | Acres | AAHU | Acres |
| Pool | 15.80 | 39.37 | 48.34 | 71.93 | 45.90 | 70.28 | 42.88 | 67.79 | 46.08 | 68.89 |
| Chute | 9.60 | 19.34 | 11.02 | 16.90 | 5.57 | 7.72 | 10.87 | 15.80 | 6.72 | 9.43 |
| Riffle | 0.52 | 1.26 | 2.50 | 4.68 | 8.46 | 14.51 | 0.15 | 0.28 | 11.00 | 18.42 |
| Chute below pool | 0.12 | 0.37 | 0.00 | 0.00 | 0.06 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dry Channel | 0.00 | 7.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Wetland | 0.00 | 0.00 | 5.19 | 6.05 | 6.28 | 7.32 | 6.40 | 7.46 | 6.65 | 7.75 |
| Scour Pool | 0.55 | 1.25 | 0.83 | 1.17 | 1.19 | 1.51 | 0.91 | 1.53 | 1.08 | 1.55 |
| Embayment | 0.01 | 0.01 | 4.13 | 5.88 | 1.73 | 2.65 | 3.84 | 5.13 | 4.07 | 5.13 |
| Tributary Mouths | 0.10 | 0.17 | 0.16 | 0.66 | 0.35 | 0.87 | 0.49 | 0.71 | 0.54 | 0.71 |
| River Remnant | 0.00 | 0.00 | 0.38 | 0.50 | 0.39 | 0.94 | 1.00 | 1.39 | 1.23 | 1.52 |
| **Total** | **26.70** | **69.23** | **72.55** | **107.77** | **69.93** | **105.92** | **66.54** | **100.09** | **77.37** | **113.40** |

Note: The without project AAHUs and acres are from Table 3-8; the design condition AAHUs and acres taken from Tables 3-20 through 3-23.

**Impact of Zone Two Riparian Vegetation (Organic Input) on Aquatic Habitat**. The contribution of the riparian zone two is captured in the computation of the SI. The difference between the organic input SI for organic input between zone one and zone two ranges between 0.01 and 0.2 for individual habitat categories for any given design condition. The larger increases are found in DC3B. The impact of the organic input SI on the aquatic HSI was not isolated in the analysis.

From an ecological perspective, the riparian system would not be fully restored without zone two. Under DC3B, the entire floodway, including side slopes, will be highly disturbed as a result of excavation and construction activity. For stability purposes, the area will need to be replanted; further, the Corps is allowed to revegetate areas disturbed during construction using native vegetation. Vegetation type E was evaluated (native forbs and grasses) to re-turf those areas. However, it has been demonstrated that Type E vegetation is more expensive to plant than Type A, C, or D and produces the least amount of habitat output. Further, it is not reasonable to leave a maintained strip of Bermuda grass within the riparian corridor as it would result in the loss of connectivity between the riparian corridor and adjacent terrestrial habitat.

Dividing the riparian corridor into riparian zone one and two was performed solely for the purpose of quantifying benefits to the stream, not to suggest that as riparian habitat one zone is more important than the other. The benefits of having a fully functioning riparian corridor are as equally important as, and intimately tied to, the aquatic restoration measures. For the San Antonio River, restoring the riparian corridor is perhaps the greatest opportunity for aquatic ecosystem restoration due to the extreme habitat degradation resulting from the loss of the riparian woodland. Defining the spatial limits of a riparian corridor differs depending on what particular function is of interest. The spatial area needed to serve a water quality function may not be as large as the area needed to serve as wildlife habitat (Fischer et al 2001). The San Antonio River study examined the amount of riparian area needed to restore, to the extent practicable, all the lost fish and wildlife functions of the previously existing riparian corridor. For the purpose of this study, the riparian corridor is considered to be the transition area between upland vegetation and the stream. In the absence of mowing, the vegetation eventually developing from the top of the banks to the edge of the stream will be riparian vegetation dependent upon the hydraulic fluctuations of the San Antonio River. Just as there is a flood inundation continuum from stream edge to top of bank, there will also be a continuum of vegetation species that are linked to the frequency of flooding. The NER plan was designed and identified to follow this natural pattern.

Further, a fully restored riparian corridor will function as the donor of nutrients, water, sediment, and the riparian vegetation as a regulator of light and temperature for the San Antonio River (Maurizi & Poillon 1992). Additionally, the restored riparian corridor will serve as a vital link between the river and the upland. Patch-size is an important habitat variable for many species of wildlife, and fragmentation is one of the leading causing of wildlife species decline and extinction. *Similar to the Everglades project, but at a smaller scale, restoration of the San Antonio River creates a unique opportunity to restore wildlife habitat function to a larger area while only working within the riverine system.* The National Park Service lands and others, which are adjacent to the river, provide an opportunity to restore the connection between the river, riparian, and upland and thus restore a large contiguous area of wildlife habitat. Reconnecting the water, riparian, and upland habitats will provide cover, woodland interior, and habitat diversity to a contiguous block of habitat for wildlife species to meet their spatial and temporal life requisites.

**Riparian Outputs**. The final array of riparian vegetation measures identified for each DC was delineated by location laterally from the river (riparian zone 1 or 2) and by vegetation type. Acreages for each vegetation type within a riparian zone were calculated using ArcMap software. These acreages and HSI values were used to establish the AAHU value for each vegetation type available within each design condition. Using the same methodology previously described for the without project condition, USFWS established HSI values for each the identified riparian vegetation types (A C, D, E) by analysis years 1, 5, 15, 25, and 50. Table 3-25 displays the acreages and AAHU outputs of the riparian vegetation for the four DCs as compared to the without project condition. Compared to the without project condition, DC1 increases riparian AAHU by 45.64, while decreasing the riparian acreages by 31.53 acres. DC2 increases AAHU by 49.29, while decreasing riparian acreages by 65.58 acres. DC3A increases riparian

**Table 3-25**
**Comparison between Without-Project and Design Conditions Riparian Habitat Acres and Average Annual Habitat Units**

| Vegetation Type | Without Project | | DC1 | | DC2 | | DC3A | | DC3B | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | AAHU | Acres | AAHU | Acres | AAHU | Acres | AAHU | Acres | AAHU |
| Bermuda, etc | 308.84 | 0.00 | 46.38 | 0.00 | 44.43 | 0.00 | 7.64 | 0.00 | 0.00 | 0.00 |
| Woodlands | 85.37 | 27.83 | 85.37 | 28.70 | 85.37 | 28.7 | 0.00 | 0.00 | 0.00 | 0.00 |
| Type A | 0.00 | 0.00 | 17.25 | 8.99 | 20.33 | 10.35 | 34.66 | 18.07 | 53.94 | 27.47 |
| Type C | 0.00 | 0.00 | 35.43 | 13.20 | 40.40 | 14.68 | 73.20 | 27.26 | 90.58 | 32.93 |
| Type D | 0.00 | 0.00 | 61.10 | 22.58 | 64.87 | 23.39 | 187.44 | 69.26 | 120.15 | 43.32 |
| Type E | 0.00 | 0.00 | 117.15 | 0.00 | 73.23 | 0.00 | 9.74 | 0.00 | 55.48 | 0.00 |
| Total Riparian Area | 394.21 | 27.83 | 362.68 | 73.47 | 328.63 | 77.12 | 312.68 | 114.59 | 320.15 | 103.72 |

AAHU by 86.76, while decreasing acreage by 81.53. DC3B increases AAHU by 75.89, while decreasing riparian acreages by 74.06.

Each one of the DC's provide significant increases to riparian AAHU, as well as converting sizable acreages to aquatic habitats. While DC3A provides the greatest increase in riparian AAHU and a concurrent decrease in riparian acreages, the objective is to focus on the aquatic portion of the ecosystem. Consequently, DC3B although having smaller gains in riparian AAHU provides greater benefit to the aquatic habitat.

**Riverine Outputs.** A major planning objective San Antonio River restoration was to restore the function of the river and riparian ecosystem. The broadest benefit will come from restoring the missing riparian component according to the USFWS, ERDC, and the TPWD. To capture the benefit to aquatic habitat, the aquatic HEP model employed variables directly related to riparian structure (organic material and vegetation cover). Average annual habitat units (AAHU) were calculated separately for aquatic and riparian restoration measures to ensure that positive impacts were occurring in each habitat. However, for the purpose of evaluating the various DCs against the without-project condition using the cost effectiveness and incremental cost analysis techniques (discussed beginning page 3-78), the aquatic and riparian AAHUs were added together to represent the riverine outputs of each plan. Riparian and aquatic outputs were considered equal in their importance to restoring a functioning riverine ecosystem. Table 3-26 compares the aquatic, riparian, and riverine AAHUs by DC. Significant increases in riverine outputs are shown by each DC over the without project outputs. DC1 increases total AAHU by 91.45, an increase of 168-percent. DC2 increases total AAHU by 88.50, an increase of 162-percent. DC3A increases total AAHU by 126.52, an increase of 232-percent. DC3B increases total AAHU by 126.45, and increase of 232-percent. Note for comparison purposes DC1 and DC2 acreages include those lands acquired for DC3A and DC3B.

**Table 3-26**
**Comparison Between Without-and With-Project Aquatic, Riparian, and Riverine Average Annual Habitat Units**

| Habitat | Without Project | | DC1 | | DC2 | | DC3A | | DC3B | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acre | AAHU | Acre | AAHU | Acre | AAHU | Acre | AAHU | Acre | AAHU |
| Aquatic | 69.23 | 26.69 | 107.77 | 72.50 | 105.92 | 69.93 | 100.09 | 66.45 | 113.40 | 77.25 |
| Riparian | 394.21 | 27.83 | 362.68 | 73.47 | 334.50 | 73.09 | 312.68 | 114.59 | 320.14 | 103.72 |
| Riverine | 463.44 | 54.52 | 470.46 | 145.97 | 440.42 | 143.02 | 412.77 | 181.04 | 433.54 | 180.97 |
| Vegetated Pilot Channel | 0.00 | 0.00 | 0.00 | 0.00 | 33.62 | 0.00 | 45.74 | 0.00 | 36.12 | 0.00 |
| Other | 19.56 | 0.00 | 12.54 | 0.00 | 8.96 | 0.00 | 24.49 | 0.00 | 13.34 | 0.00 |
| Total Project | 483.00 | 54.52 | 483.00 | 145.97 | 483.00 | 143.02 | 483.00 | 181.04 | 483.00 | 180.97 |
| Aquatic AAHU % Increase | --- | --- | --- | 172% | --- | 162% | --- | 149% | --- | 190% |
| Total AAHU % Increase | --- | --- | --- | 168% | --- | 162% | --- | 232% | --- | 232% |

Average annual habitat units (AAHU) are used for the cost effective/incremental cost analysis to compare the different restoration measures. Using AAHUs, the 483 acres of the recommended plan produce an average of 180.98 habitat units annually for the analysis period beginning with year 1 and ending with year 50. However, reporting average annual habitat units during the maturation phase of the recommended plan does not provide a true accounting of the benefits to be provided once the project has reached maturity. The aquatic and riparian components of the riverine environment will mature at different points in time. The aquatic habitats will be producing habitat units at a relatively mature level by year 25; however, the riparian habitat will still be maturing at year 50. To demonstrate the disparity in maturation speed, Table 3-27 provides a comparison of the average HSI and corresponding HU outputs for years 1, 25, and 50 for the aquatic and riparian components of the recommended plan.

**Table 3-27**
**Comparison of Habitat Units Over Time**

| | Aquatic Habitats | | | Riparian Habitats | | |
|---|---|---|---|---|---|---|
| Analysis Year | Acres | Average HSI | HU | Acres | Average HSI | HU |
| 1 | 113 | 0.41 | 46.44 | 356 | 0.21 | 75.83 |
| 25 | 113 | 0.69 | 77.86 | 356 | 0.40 | 142.40 |
| 50 | 113 | 0.70 | 78.65 | 356 | 0.78 | 276.61 |

For aquatic habitats, the rate of growth in habitat outputs slows between years 25 and 50, 0.69 and 0.70 HSI respectively. However, the riparian habitat exhibits the largest rate of growth during this same 25-year period with HSI values of 0.40 in year 25 and 0.78 in year 50. These numbers indicate that as a riverine environment the project begins to reach maturity at the end of the period of analysis. Using analysis years 15, 25, 50, and 75 to annualize the outputs of the project reveals that the riverine environment will produce on average 273.49 habitat units annually. Assuming that the highest average HSI potential for both habitats was 0.8, the total outputs upon maturity will be approximately 375 habitat units per year. This is a substantial increase over the 180.98 AAHUs used for the CE/ICA.

Fifty years may seem to be a long time for the project to reach maturity and produce the projected level of output, but the length of time is directly related to the level of degradation that has occurred within the study area. Currently, a riverine ecosystem does not exist within the mission reach study area. The riparian habitat is non-existent, and the aquatic habitat suffers severe degradation, largely due to the absence of a functioning riparian corridor. The recommended plan would put into place the components necessary to allow ecological processes to begin building the synergy necessary for a riverine ecosystem. Habitat outputs will be maximized when both the aquatic and riparian components have matured to form a single integrated riverine system. At that time, conservative habitat quality projections indicate the project would be functioning at 80% of optimum.

## COST EFFECTIVENESS AND INCREMENTAL COST ANALYSIS (CE/ICA)

The U.S. Army Corps of Engineers, Institute of Water Resources, developed the software used to conduct CE/ICA (IWR-PLAN Version 3.3). IWR-PLAN has been used to evaluate all measures using average annual habitat unit gains versus average annual costs. The software evaluates all measures (incrementally) for cost effectiveness to determine which combinations provide the greatest AAHU gains for the annualized cost. The analyses require three types of data: measures, estimates of each measure's output, and estimates of each measure's cost. The following sections describe the specific inputs into IWR-PLAN, the process for conducting the analysis, and the outputs generated by IWR-PLAN.

Cost effectiveness and incremental cost analyses (CE/ICA) are the tools used to provide a framework for comparing the dollar costs and non-dollar outputs associated with restoration measures. *Cost effectiveness* identifies the least cost solution for each possible level of output under consideration as well as those measures that provide more output for equal or less costs than others. The subsequent incremental cost analysis reveals the increases in cost that accompany increases in output, identifying those measures which provide the greatest return in output per dollar invested, or "best-buys." CE/ICA frames the question: "*As the scale of the project is increased, is each subsequent level of additional output worth its additional cost?*"

**Implementation Costs**. Implementation costs were developed for real estate acquisition, pilot channel, riffle structures, outfall modifications, invert slope protection, erosion protection, embayments, tributary mouths, opening river remnants, wetlands, planting vegetation, bridge modifications, utility, road, and sidewalk relocations, pre-construction engineering and design, and supervision and administration. The development of these costs is described briefly below. Most unit costs were based on industry standards, discussions with manufacturers and material providers, and experience with recent projects.

*Real Estate Acquisition*. Included both project lands and the disposal area. Real estate costs were estimated using the latest county appraisal values. Real estate costs were allocated to both the pilot channel and vegetation, and apportioned by vegetation type and acres.

*Care of Water.* Care of water for all design conditions was based on pumps sizes, number of pumps, and operation times. Care of water is allocated to the pilot channel.

*Pilot channel.* Excavation quantities were developed for DC1 by using the HEC-RAS hydraulic model program. A comparison was made of the existing condition versus the improved condition. A constant water surface elevation was forced into each cross section with a flow of one cfs. This provided an output table for accumulated volume in the channel. The difference in volume estimated the excavation quantity. Excavation quantities for DC2, DC3A and DC3B were estimated in similar fashion.

*Riffle structures.* Preliminary design sketches and quantities were developed for four types of riffle structures. They included using an inverted “T” concrete wall with riprap placed up- and downstream of the structure, using limestone blocks with riprap placed up- and downstream of the blocks, and using placing riprap over an impervious fill material (rubble, etc filled with grout), and placing riprap without any type of impervious structure. The grouted rubble material was removed from further consideration on environmental and structural integrity concerns. Preliminary design sketches were developed for the inverted “T” concrete wall and limestone block wall with riprap placed up- and downstream of the structure. Based on the sketches, quantities were estimated and unit costs developed.

*Outfall replacement and/or modifications.* The project area contains over 100 outfalls. The outfalls are comprised of several different types including concrete and grass swales, grouted swales, corrugated metal pipe, reinforced concrete pipe, and box culverts. Under DC3A and DC3B, where excavation is occurring outside of the existing Federal project right of way, outfall replacement will be required for virtually all of the affected outfall structures. The new outfall structures will be a grated inlet to intercept drainage into a drop structure and outflow pipe. The outlet pipe may either terminate at the edge of the pilot channel or terminate with a stone headwall and allowed to flow over a stone terrace. The existing outflow structure may be tied into this replacement structure. Preliminary design sketches, quantities, and unit costs were developed for three different outfall configurations, small, medium, and large. Under DC1 and DC2, outfall modifications (as opposed to replacement) will be required. Given the relatively smaller amounts of excavation required under these design conditions, only the disturbed portion of the outfall will be replaced with placed riprap. In other instances, the outfalls will be modified to restore an embayment or tributary mouth. Some outfall will not be disturbed under any design condition. For cost effectiveness and incremental cost analyses purposes, outfall costs are allocated either to the pilot channel, vegetation (when excavation for conveyance has disturbed the outfall), or embayments.

*Invert slope protection.* There are two areas downstream of Ashley Road requiring invert slope protection (channel bottom) against high velocities, and to maximize the sediment transport efficiency of the pilot channel. The preliminary design calls for placed riprap in these areas. A basic quantity take-off by on area and thickness was estimated, and a unit cost developed. The invert slope protection is included in DC2, 3A, and 3B.

*Erosion protection.* The question of what happens to the vegetation and land shape outside of the pilot channel if a flood occurs before the vegetation can become established was considered. In order protect newly planted vegetation, protection measures are incorporated into each design condition. Three categories were used to gauge the need. Shear stresses less than or equal to 0.5 are considered safe from significant erosion. Reaches labeled medium evidenced shear stresses ranging between 0.5 and 1.0. Temporary protection until vegetation is established is a must for in-channel overbank areas in this range. The third range was labeled high because they exhibited shear stress values exceeding 1.0. Virtually all of the pilot channel values in storms exceeding the channel-forming flow fell into this category. The type of protection considered included erosion control fabric, turf reinforcement mats, sod and woven coir fabric, coir fabric wrapped soil lifts, geogrid and coir fabric wrapped soil lifts, and vegetated geocell. Erosion control fabric was selected for lower shear stresses and turf reinforcement mats for higher shear stresses. Basic quantity take-offs were estimated based on area required, and unit costs developed.

*Embayments.* Under DC1, costs associated with embayments include excavation, riprap, and outfall modifications. Under DC2, DC3A, and DC3B costs are limited to excavation and riprap (as outfall costs are allocated to either the pilot channel or vegetation). Therefore, for DC2, DC3A, and DC3B, these costs were allocated to the pilot channel.

*Tributary mouths.* Under DC1, costs associated with tributary mouths include excavation, riprap, outfall modifications, and tributary outfalls. Under DC2, DC3A, and DC3B costs are limited to excavation and riprap (as outfall costs are allocated to either the pilot channel or vegetation.

*Opening river remnants.* Under DC1, DC2, DC3A, and DC3B, one river remnant was identified for restoration the San Juan Diversion (just upstream of Ashley Road). This would involve the removal of an existing headwall and culvert pipe, excavation of the open channel, and a new headwall at the downstream end. For DC2, DC3A, and DC3B, a second remnant would be restored downstream of Interstate Highway 410. This would involve excavation and the removal of culvert/pipe structure. Based on preliminary design sketches, quantities were estimated and unit costs developed.

*Wetlands.* Under DC1, a riffle structure was identified just downstream of Ashley Road. The purpose of this structure is to impound water for a wetland. Costs of this structure are allocated to the wetlands. For DC2, DC3A, and DC3-B, a similar structure in the area is required for sediment transport. And although it also creates a wetland, its cost is allocated to the pilot channel. A preliminary design was developed, quantities and unit costs estimated.

*Vegetation.* Vegetation costs were developed for planting, weed control, and irrigation for each vegetation type. Planting costs include soil preparation, materials, labor and equipment. Other costs allocated to planting include excavation, outfall modifications, and road and sidewalk relocations when directly associated with effort to create additional conveyance.

*Bridge modifications.* Under DC3A and DC3B, the current slope paving under the East Southcross and East White bridges will be replaced with vertical walls. These modifications will provide additional conveyance under the bridge and allow greater amounts of vegetation. For this reason, bridge modification costs are allocated to vegetation, and apportioned by type and acres. The preliminary design identifies an inverted “T” concrete wall. Based on preliminary sketches, quantities were estimated and unit costs applied.

*Utility relocations.* Quantities and unit costs were developed for know locations of gas, water, sewer, and electrical utilities using industry standard criteria. Utility relocation costs were allocated to pilot channel costs.

*Road relocations.* Under DC3A and DC3B, portions of Mission Parkway will be removed and replaced. The road is being replaced as a result of excavation outside of the existing right-of-way for additional conveyance. Preliminary quantities and unit costs were developed using industry standard criteria. Costs are allocated to vegetation types by acre.

*Sidewalk relocations.* Preliminary designs, quantities and unit costs were developed using industry standard criteria. Under DC3A and DC3B, portions existing sidewalks in Mission and Padre Park are replaced as a result of excavation outside of the existing right-of-way for additional conveyance (vegetation). Preliminary quantities and unit costs were developed using industry standard criteria. Costs are allocated to vegetation types by acre.

*Pre-construction engineering and design.* A flat rate of 10-percent of the implementation cost was used to estimate pre-construction engineering and design costs.

*Supervision and administration.* Six-percent of the implementation cost was used to estimate supervision and administration costs.

**Table 3-28**
**Implementation Cost [1]**
**($000 – January 2004 price level)**

| Project Feature | DC-1 | DC-2 | DC-3A | DC-3B |
|---|---|---|---|---|
| Channel Modifications/ Pilot Channel: | | | | |
| Lands and Damages | 1,095.0 | 1,095.0 | 676.8 | 666.7 |
| Utility Relocations | 2,049.1 | 1,974.2 | 2,642.1 | 2,642.1 |
| Outfall Modifications | 55.4 | 102.2 | 2,972.9 | 2,972.9 |
| Care of Water | 2,551.9 | 2,551.9 | 2,551.9 | 2,551.9 |
| Clearing and Grubbing | 392.5 | 338.3 | 829.6 | 543.5 |
| Remove/Modify Existing Structures | 377.3 | 385.9 | 385.9 | 385.9 |
| Excavation and Hauling | 5,893.7 | 5,176.1 | 5,768.2 | 3,444.0 |
| Embankment at Site | 31.7 | 203.4 | 1,275.2 | 1,275.2 |
| Erosion Control – Temporary | 430.7 | 430.7 | 430.7 | 430.7 |
| Erosion Control – Vegetation | 13,275.2 | 11,543.7 | 11,543.7 | 11,543.7 |
| Erosion Control – Invert | 0.0 | 368.0 | 368.0 | 368.0 |
| Riffle Structures | 5,644.7 | 4,723.4 | 4,723.4 | 4,723.4 |
| **Total Channel** | **31,797.4** | **28,892.8** | **34,168.4** | **31,548.0** |
| Special Aquatic Features: | | | | |
| Wetland [6] | 470.9 | 20.6 | 20.6 | 20.6 |
| River Remnants | 382.6 | 530.4 | 530.4 | 530.4 |
| Embayments | 740.1 | 136.7 | 175.5 | 175.5 |
| Tributaries | 767.0 | 773.7 | 777.3 | 777.3 |
| **Total Special Aquatic Features** | **2,360.6** | **1,461.4** | **1,503.8** | **1,503.8** |
| Vegetation | | | | |
| Type A | | | | |
| Lands and Damages | 0.0 | 0.0 | 204.4 | 349.4 |
| Bridge/Road/Sidewalk Relocations | 0.0 | 0.0 | 123.5 | 213.1 |
| Outfall Modifications | 0.0 | 0.0 | 129.3 | 222.9 |
| Excavation and Hauling | 0.0 | 0.0 | 1,451.6 | 2,503.7 |
| Embankment at Site | 0.0 | 0.0 | 165.7 | 285.7 |
| Planting | 358.1 | 417.5 | 644.7 | 1,003.4 |
| Total Type A | 358.1 | 417.5 | 2,719.2 | 4,578.5 |
| Type C | | | | |
| Lands and Damages | 0.0 | 0.0 | 431.7 | 582.6 |
| Bridge/Road/Sidewalk Relocations | 0.0 | 0.0 | 260.9 | 360.0 |
| Outfall Modifications | 0.0 | 0.0 | 273.0 | 377.5 |
| Excavation and Hauling | 0.0 | 0.0 | 3,065.7 | 4,239.8 |
| Embankment at Site | 0.0 | 0.0 | 349.9 | 483.9 |
| Planting | 762.4 | 855.8 | 1,416.8 | 1,767.7 |
| Total Type C | 762.4 | 855.8 | 5,798.1 | 7,811.5 |
| Type D | | | | |
| Lands and Damages | 0.0 | 0.0 | 1,105.4 | 819.8 |
| Bridge/Road/Sidewalk Relocations | 0.0 | 0.0 | 668.1 | 478.7 |
| Outfall Modifications | 0.0 | 0.0 | 699.0 | 500.8 |
| Excavation and Hauling | 0.0 | 0.0 | 7,850.2 | 5,623.9 |
| Embankment at Site | 0.0 | 0.0 | 896.0 | 641.9 |
| Planting | 1,362.5 | 1,424.9 | 3,774.6 | 2,438.8 |
| Total Type D | 1,362.5 | 1,424.9 | 14,963.7 | 10,503.9 |
| Type E | | | | |
| Planting | 980.7 | 613.1 | 94.6 | 464.5 |
| **Total Vegetation** | **3,463.8** | **3,311.3** | **23,575.5** | **23,350.4** |
| Subtotal Incremental Cost Analysis | 37,621.8 | 33,664.8 | 58,124.6 | 56,810.8 |
| PED | 3,652.7 | 3,2567.0 | 5,573.2 | 5,439.2 |
| S&A | 2,191.6 | 1,954.2 | 3,343.9 | 3,263.5 |
| **Total Incremental Cost Analysis** | **43,466.1** | **38,876.1** | **67,041.6** | **65,513.5** |

[1] Does not include contingencies; totals may not sum due to rounding

**Table 3-29**
**Average Annual Implementation Cost**
**Pilot Channel and Special Aquatic Features**
**For CE/ICA Analysis**
**($000; January 2004 price level; 8 –5/8 percent; 50-year period of analysis)**

| | Design Condition 1 | | Design Condition 2 | | Design Condition 3A | | Design Condition 3B | |
|---|---|---|---|---|---|---|---|---|
| Project Feature | Total First Cost | Ave Annual Cost | Total First Cost | Ave Annual Cost | Total First Cost | Ave Annual Cost | Total First Cost | Ave Annual Cost |
| Pilot Channel | 36,709.8 | 2,388.3 | 33,339.8 | 2,169.0 | 38,208.8 | 2,485.8 | 36,952.8 | 2,404.1 |
| Concepcion Park Embay. | 40.1 | 2.5 | na | na | na | na | na | na |
| Concepcion Creek Embay | 14.0 | 0.8 | na | na | na | na | na | na |
| Concepcion Cr, North, Embay | na | na | na | na | 6.0 | 0.4 | 6.0 | 0.4 |
| Conception Cr, South, Embay | na | na | na | na | 62.3 | 3.8 | 62.3 | 3.8 |
| Concepcion Creek Trib Mouth | 889.7 | 54.0 | na | na | 889.7 | 54.0 | 889.7 | 54.0 |
| Ballpark Embayment | na | na | 44.6 | 2.7 | 17.1 | 1.0 | 17.1 | 1.0 |
| Golf Course Trib Mouth | na | na | na | na | 3.0 | 0.2 | 3.0 | 0.2 |
| Golf Course Embayment | na | na | 10.8 | 0.7 | na | na | na | na |
| Mission County Park Embay | na | na | 30.7 | 1.9 | na | na | na | na |
| E. Southcross Ave Embay | 118.5 | 7.2 | na | na | na | na | na | na |
| Mission Road Embay | 26.2 | 1.6 | na | na | na | na | na | na |
| E. White Ave Embay | 195.3 | 11.8 | na | na | na | na | na | na |
| Hot Wells Embayment | 58.2 | 3.5 | na | na | na | na | na | na |
| Hot Wells, North, Embay | na | na | na | na | 4.8 | 0.3 | 3.0 | 0.2 |
| Hot Wells, South, Embay | na | na | na | na | 38.5 | 2.3 | 38.5 | 2.3 |
| Hot Wells Trib Mouth | na | na | na | na | 3.3 | 0.2 | 3.3 | 0.2 |
| Berg's Mill Trib Mouth | na | na | na | na | 3.0 | 0.2 | 3.0 | 0.2 |
| Berg's Mill Embay | na | na | na | na | 15.1 | 0.9 | 15.1 | 0.9 |
| San Juan Trib Mouth | na | na | 2.3 | 0.1 | na | na | na | na |
| Ashley Road Trib Mouth | na | na | 3.6 | 0.2 | na | na | na | na |
| No Name Trib Mouth | na | na | 1.8 | 0.1 | na | na | na | na |
| San Juan River Remnant | 443.7 | 27.1 | 443.7 | 27.1 | 443.7 | 27.1 | 443.7 | 27.1 |
| Ashley Road Wetland | 546.3 | 33.4 | 23.9 | 1.4 | 23.9 | 1.4 | 23.9 | 1.4 |
| Espada Mission Restored Remnant | na | na | na | na | 171.4 | 10.5 | 171.4 | 10.5 |
| Brown Park Embayment | 332.1 | 20.1 | 28.9 | 1.7 | 5.2 | 0.3 | 5.2 | 0.3 |
| Mission Espada Embayment | 73.1 | 4.4 | 43.6 | 2.6 | 28.6 | 1.7 | 28.6 | 1.7 |

**Table 3-30**
**Average Annual Implementation Cost**
**Riparian Vegetation**
**For CE/ICA Analysis**
**($000; January 2004 price level; 8 –5/8 percent; 50-year period of analysis)**

| | Total Project Cost | Total Average Annual Cost | Average Annual Cost per Acre |
|---|---|---|---|
| Design Condition 1 | | | |
| Type A | 415.5 | 26.5 | 1.5 |
| Type C | 884.3 | 56.3 | 1.6 |
| Type D | 1,580.5 | 100.7 | 1.6 |
| Type E | 1,137.7 | 72.5 | 0.6 |
| Design Condition 2 | | | |
| Type A | 484.3 | 30.9 | 1.5 |
| Type C | 992.7 | 63.2 | 1.6 |
| Type D | 1,652.9 | 105.3 | 1.6 |
| Type E | 711.2 | 45.3 | 0.6 |
| Design Condition 3A | | | |
| Type A | 3,121.5 | 198.9 | 5.7 |
| Type C | 6,556.7 | 424.1 | 5.8 |
| Type D | 17,215.8 | 1,096.8 | 5.9 |
| Type E | 94.6 | 6.0 | 0.6 |
| Design Condition 3B | | | |
| Type A | 5,255.1 | 334.8 | 6.2 |
| Type C | 8,969.2 | 571.4 | 6.3 |
| Type D | 12,053.4 | 767.9 | 6.4 |
| Type E | 538.8 | 34.3 | 0.6 |

All cost estimates were developed at a January 2004 price level. Costs are converted to average annual costs using the applicable Federal interest rate of 5-5/8 percent over a 50-year period of analysis. The average annual costs is used in the cost effectiveness and incremental cost analysis. Table 3-28 through Table 3-30 displays cost summaries for DC1, DC2, DC3A, and DC3B.

**CE/ICA Screening of Special Aquatic Measures**. For the final CE/ICA, fully formed incremental plans were input into IWR-PLAN. To facilitate building these fully formed plans, a screening CE/ICA was performed using the special aquatic measures identified for each design condition. The purpose of the screening analysis was to narrow the number of combinations to only those that were cost-effective, and to carry those cost-effective forward to the final analysis. This screening CE/ICA is designed to answer the question: "*For each design condition, what combination of special aquatic measures are cost-effective and provide the best incremental output for the incremental cost*?"

Tributary mouths, embayments, restored remnants, and wetlands are rare to non-existent in the study area. These measures are considered extremely important to the aquatic environment and to restoration of the riverine system. The channel modifications, riparian restoration, and special aquatic features all work in concert to improve the riverine system. For these reasons, several "best buy" plans are carried forward for consideration in combination with the channel modifications and riparian restoration measures in the CE/ICA final run. For the preliminary analysis, costs are assumed to be justified by the outputs. During the screening analysis, there were a total of 60 best-buy combinations identified: 12 for DC1, 13 for DC2, 17 for DC3A, and 18 for DC3B. To further narrow the number of combinations carried forward to the final analysis, breakpoints in cost were used as preliminary delineation points. Final incremental justification for the cost based upon the environmental outputs was provided during the final analysis.

For each design condition, the average annual habitat units (AAHU) gained and average annual cost (AAC) for each individual special aquatic measure (wetland, embayment, tributary mouth, restored remnant) were input to IWR-PLAN. The plan formulation function was utilized whereby all measures were combinable with each other. Construction of any of the special aquatic measures would be dependent upon the channel modification included with a particular design condition. Further, because restoration of the riparian corridor has been identified by the resource agencies as the single most important measure for restoration, and the aquatic measures all rely on riparian variables, it would be impractical to construct special aquatic measures prior to the riparian restoration. Therefore, the assumption was made that no special aquatic measures would be implemented without first planting the riparian corridor, and the HSI values were calculated using the riparian vegetation plan developed for each design condition.

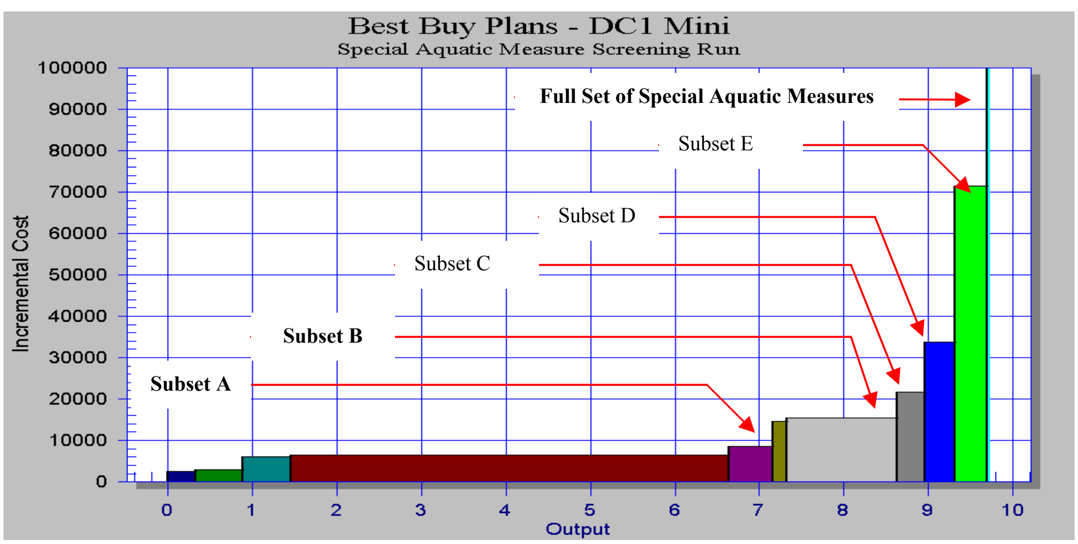
**Design Condition 1 - Special Aquatic Subsets**. DC1 includes 11 special aquatic measures and the no action plan. IWR-PLAN identified 2,048 combinations, of which 50 combinations were identified as cost effective, and 12 combinations were identified as best buys. Table 3-31 presents the CE/ICA output for the special aquatic subset screening. The solution increment column is cumulative starting with the Conception Creek Embayment such that the next row identifies only the incremental measure added to the previous combination. Figure 3-11 is a graphical representation of the 12 best buy combinations.

Eleven of the twelve best buys will be carried forward into the final CE/ICA. In addition to the no action measure, the remaining measures are grouped into five combinations of best buys. The combinations reflect an assessment of the reasonableness of the incremental average annual cost per incremental average annual habitat unit. Subset (a) includes the Concepcion Creek, Mission Road, Hot Wells, and Mission Espada embayment, and the Ashly Road Wetland. Subset (b) includes subset (a) plus the Concepcion Park and Brown Park embayments. Subset (c) includes subset (b) plus the East Southcross embayment. Subset (d) includes subset (c) plus the East White Avenue embayment, and subset (e) includes subset (d) plus the San Juan river remnant.

**Table 3-31**
**Summary of Special Aquatic Features**
**Design Condition 1**

| Solution Increment | Increm AAHU | AAHU (cumul) | AAC (cum) | AAC per AAHU (cum) | Increm Cost (IC) | IC per AAHU |
|---|---|---|---|---|---|---|
| ***No Action*** | 0.00 | 0.00 | $0 | na | na | na |
| Concepcion Creek Embayment | 0.33 | 0.33 | $847 | $2,567 | $847 | $2,567 |
| Mission Road Embayment | 0.55 | 0.88 | $2,432 | $2,764 | $1,585 | $2,882 |
| Hot Wells Embayment | 0.57 | 1.45 | $5,946 | $4,101 | $3,514 | $6,165 |
| Ashley Road Wetland | 5.19 | 6.64 | $39,333 | $5,924 | $33,387 | $6,433 |
| Mission Espada Embayment (subset a) | 0.52 | 7.16 | $43,747 | $6,110 | $4,414 | $8,490 |
| Concepcion Park Embayment | 0.17 | 7.33 | $46,219 | $6,305 | $2,472 | $14,541 |
| Brown Park Embayment (subset b) | 1.30 | 8.63 | $66,290 | $7,681 | $20,071 | $15,440 |
| E. Southcross Ave Embayment (subset c) | 0.33 | 8.96 | $73,450 | $8,198 | $7,160 | $21,697 |
| E. White Ave Embayment (subset d) | 0.35 | 9.31 | $85,255 | $9,157 | $11,805 | $33,729 |
| San Juan Restored Remnant (subset e) | 0.38 | 9.69 | $112,378 | $11,597 | $27,123 | $71,376 |
| Concepcion Creek Tributary Mouth | 0.04 | 9.73 | $166,383 | $17,100 | $54,005 | $1,350,125 |

**Figure 3-11**
**Graphical Incremental Cost and Output for Special Aquatic Measures**
**Design Condition 1**



The remaining best buy, the Concepcion Creek tributary mouth was not included in any subset, or carried forward to the final CE/ICA. This tributary mouth requires the replacement of the existing outfall structure with a similar structure able to withstand the potential high flows and velocities at this location. The incremental cost per AAHU ($1,350,125) was not worth the incremental output provided (0.04 AAHU).

**Design Condition 2 - Special Aquatic Subsets**. DC2 includes 12 special aquatic measures and the no action plan. IWR-PLAN identified 4,096 combinations of special aquatic measures, which 60 combinations were identified as cost effective, and 13 combinations were identified as best buys. Table 3-32 presents the IWR-Plan output for the special screening CE/ICA. The solution increment column is cumulative starting with the Ashley Road Wetland such that the next row identifies only the incremental measure added to the previous combination. Figure 3-12 is a graphical representation of the 12 best buy combinations

Twelve of the thirteen best buys will be carried forward into the final CE/ICA. In addition to the no action measure, the remaining measures are grouped into six combinations of best buys. The combinations reflect an assessment of the reasonableness of the incremental average annual cost per incremental average annual habitat unit. Subset (a) includes the Ashley Road wetland, the No Name, San Juan, and Ashley Road tributary mouths, and the Espada Mission and Brown Park Embayments. Subset (b) includes subset (a) plus the Mission County Park embayment, and Subset (c) includes subset (b) plus the Ball Park embayment. Subset (d) includes subset (c) plus the golf course embayment, and subset (e) includes subset (d) plus the Espada Mission river remnant. Subset (f) includes subset (e) plus the San Juan river remnant.

Similarly to DC1, Conception Creek tributary mouth is not carried forward into the final CE/ICA given the unreasonableness of the incremental cost per AAHU ($2,687,950) compared to the incremental output provided (0.02 AAHU).

**Design Condition 3A - Special Aquatic Subsets**. DC3A includes 16 special aquatic measures and the no action plan. IWR-PLAN identified 131,072 combinations of special aquatic measures, of which 491 combinations were identified as cost effective, and 17 combinations were identified as best buys. Table 3-33 presents the IWR-Plan output for the special screening CE/ICA of DC3A. The solution increment column is cumulative starting with the Ashley Road wetland such that the next row identifies only the incremental measure added to the previous combination. Figure 3-13 is a graphical representation of the 17 best buy combinations

Sixteen of the seventeen best buys will be carried forward into the final CE/ICA. In addition to the no action measure, the remaining measures will be grouped into two combinations of best buys. The combinations reflect an assessment of the reasonableness of the incremental average annual cost per incremental average annual habitat unit. Subset (a) includes all the Ashley Road wetland, and all identified tributary mouths and embayments. Subset (b) includes subset (a) plus the Mission Espada river remnant and the San Juan river remnant. The Conception Creek tributary mouth, having an incremental cost per AAHU of $537,595

**Table 3-32**
**Summary of Special Aquatic Features**
**Design Condition 2**

| Solution Increment | Increm AAHU | AAHU (cumul) | AAC (cum) | AAC per AAHU (cum) | Increm Cost (IC) | IC per AAHU |
|---|---|---|---|---|---|---|
| ***No Action*** | 0.00 | 0.00 | $0.00 | n/a | n/a | n/a |
| Ashley Road Wetland | 6.28 | 6.28 | $1,443 | $230 | $1,443 | $230 |
| No Name Trib Mouth | 0.10 | 6.38 | $1,552 | $243 | $109 | $1,090 |
| San Juan Trib Mouth | 0.06 | 6.44 | $1,695 | $263 | $143 | $2,383 |
| Ashley Road Trib Mouth | 0.08 | 6.52 | $1,910 | $293 | $215 | $2,688 |
| Espada Mission Embayment | 0.63 | 7.15 | $4,547 | $636 | $2,637 | $4,186 |
| Brown Park Embayment (subset a) | 0.38 | 7.53 | $6,291 | $835 | $1,744 | $4,589 |
| Mission County Park Embayment (subset b) | 0.21 | 7.74 | $8,143 | $1,052 | $1,852 | $8,819 |
| Ballpark Embayment (subset c) | 0.19 | 7.93 | $10,835 | $1,366 | $2,692 | $14,168 |
| Golf Course Embayment (subset d) | 0.03 | 7.96 | $11,486 | $1,443 | $651 | $21,700 |
| Espada Mission Remnant (subset e) | 0.32 | 8.28 | $21,964 | $2,653 | $10,478 | $32,744 |
| San Juan Remnant (subset f) | 0.39 | 8.67 | $49,087 | $5,662 | $21,123 | $69,546 |
| Conception Creek Trib Mouth | 0.02 | 8.69 | $102,846 | $11,835 | $53,759 | $2,687,950 |

**Figure 3-12**
**Graphical Incremental Cost and Output for Special Aquatic Measures**
**Design Condition 2**

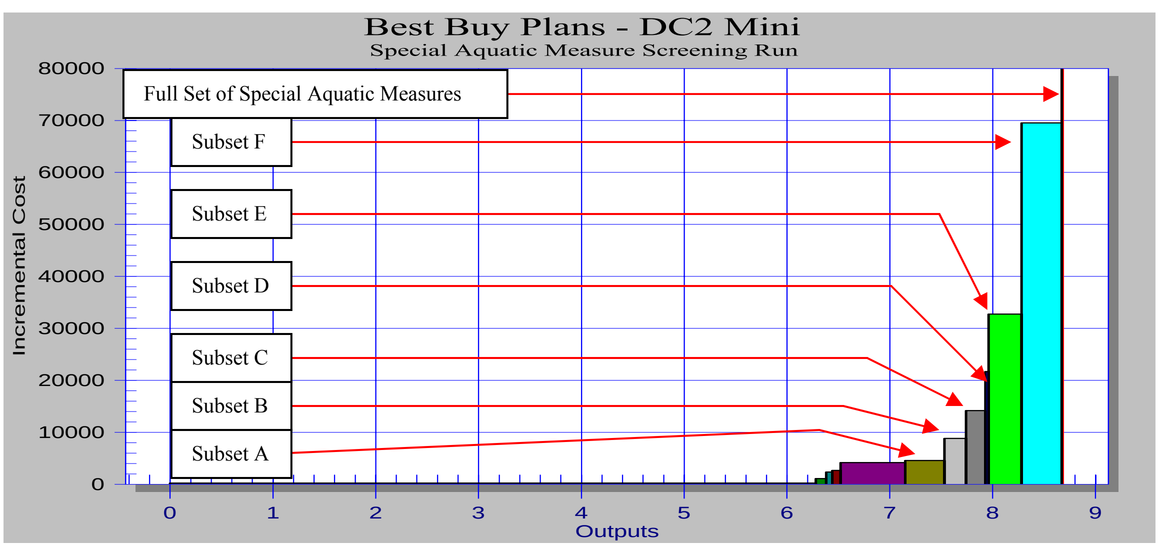
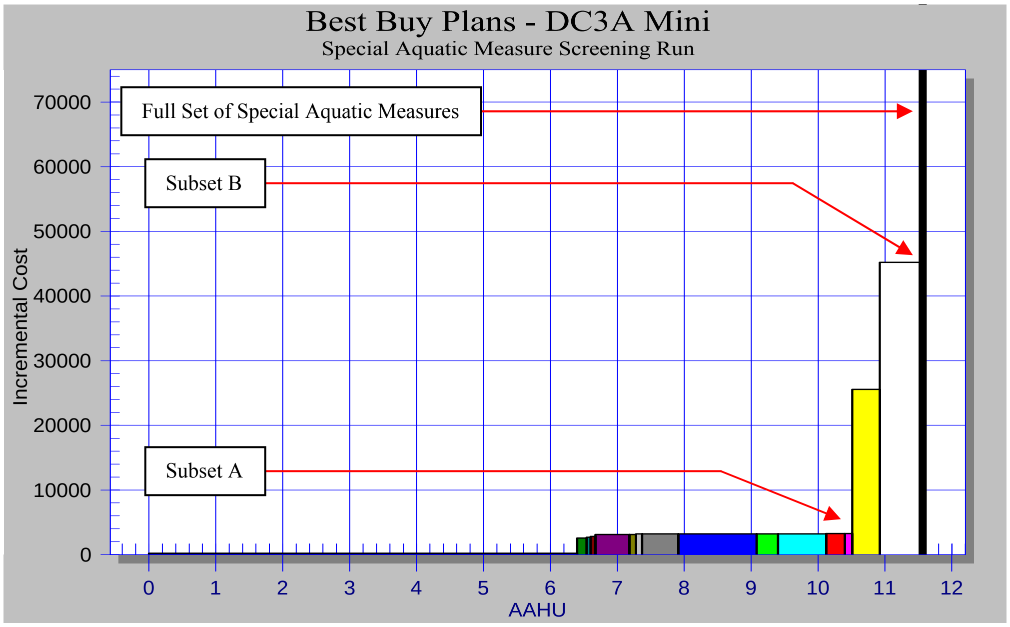


**Table 3-33**
**Summary of Special Aquatic Features**
**Design Condition 3 A**

| Solution Increment | Increm AAHU | AAHU (cumul) | AAC (cum) | AAC per AAHU (cum) | Increm Cost (IC) | IC per AAHU |
|---|---|---|---|---|---|---|
| ***No Action*** | 0.00 | 0.00 | $0 | na | na | na |
| Ashley Road Wetland | 6.40 | 6.40 | $1,460 | $228 | $1,460 | $228 |
| Golf Course & Bergs Mill Trib Mouth | 0.14 | 6.54 | 1,820 | 278 | 360 | 2,570 |
| Ball Park Trib Mouth | 0.06 | 6.60 | 1,982 | 300 | 162 | 2,699 |
| Hot Wells Trib Mouth | 0.07 | 6.67 | 2,179 | 327 | 198 | 2,827 |
| Ashley Road Embayment | 0.51 | 7.18 | 3,762 | 524 | 1,582 | 3,102 |
| Brown Park Embayment | 0.10 | 7.28 | 4,073 | 560 | 312 | 3,116 |
| Hotwells North Embayment | 0.09 | 7.37 | 4,361 | 592 | 288 | 3,196 |
| Mission Espada Embayment | 0.54 | 7.91 | 6,087 | 770 | 1,726 | 3,196 |
| Conception Creek South Embayment | 1.17 | 9.08 | 9,851 | 1,085 | 3,764 | 3,217 |
| Ball Park Embayment | 0.32 | 9.40 | 10,882 | 1,158 | 1,031 | 3,221 |
| Hotwells South Embayment | 0.72 | 10.12 | 13,207 | 1,305 | 2,325 | 3,230 |
| Bergs Mill Embayment | 0.28 | 10.40 | 14,118 | 1,358 | 911 | 3,253 |
| Conception Creek North Embayment (subset a) | 0.11 | 10.51 | 14,478 | 1,378 | 360 | 3,269 |
| Mission Espada Restored Remnant | 0.41 | 10.92 | 24,956 | 2,285 | 10,478 | 25,557 |
| San Juan Restored Remnant (subset b) | 0.60 | 11.52 | 52,079 | 4,521 | 27,123 | 45,205 |
| Conception Creek Trib Mouth | 0.10 | 11.62 | 105,839 | 9,108 | 53,760 | 537,595 |

**Figure 3-13**
**Graphical Incremental Cost and Output for Special Aquatic Measures**
**Design Condition 3A**




versus an incremental output provided of 0.10 OAHU, was not carried forward to the final CE/ICA.

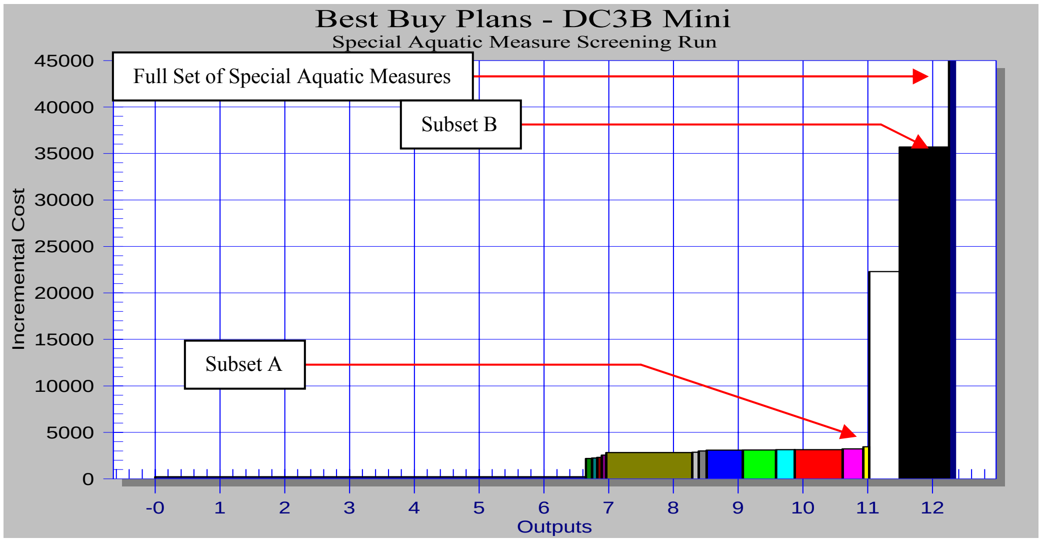
**Design Condition 3B - Special Aquatic Subsets**. DC3B includes 17 special aquatic measures and the no action plan. IWR-PLAN identified 31,072 combinations of special aquatic measures, of which 329 combinations were identified as cost effective, and 18 combinations were identified as best buys. The solution increment column is cumulative starting with the Ashley Road Wetland such that the next row identifies only the incremental measure added to the previous combination. Table 3-34 presents the IWR-Plan output for the special screening CE/ICA of DC3B. The solution increment column is cumulative starting with the Ashley Road wetland such that the next row identifies only the incremental measure added to the previous combination. Figure 3-14 is a graphical representation of the 18 best buy combinations

Seventeen of the eighteen best buys will be carried forward into the final CE/ICA. In addition to the no action measure, the remaining measures will be grouped into two combinations of best buys. The combinations reflect an assessment of the reasonableness of the incremental average annual cost per incremental average annual habitat unit. Subset (a) includes all the Ashley Road wetland, and all identified tributary mouths and embayments. Subset (b) includes subset (a) plus the Mission Espada river remnant and the San Juan river remnant. The Conception Creek tributary mouth, having an incremental cost per AAHU of

**Table 3-34**
**Summary of Special Aquatic Features**
**Design Condition 3B**

| Solution Increment | Increm AAHU | AAHU (cumul) | AAC (cum) | AAC per AAHU (cum) | Increm Cost (IC) | IC per AAHU |
|---|---|---|---|---|---|---|
| ***No Action*** | 0.00 | 0.00 | $0 | na | na | na |
| Ashley Road Wetland | 6.65 | 6.65 | $1,459 | $219 | $1,459 | $219 |
| Hotwells Trib Mouth | 0.09 | 6.74 | $1,656 | $246 | $197 | $2,189 |
| Golf Course Trib Mouth | 0.08 | 6.82 | $1,835 | $269 | $179 | $2,238 |
| Ball Park Trib Mouth | 0.07 | 6.89 | $1,996 | $290 | $161 | $2,300 |
| Berg's Mill Trib Mouth | 0.07 | 6.96 | $2,175 | $313 | $179 | $2,557 |
| Conception Creek South Embayment | 1.33 | 8.29 | $5,938 | $716 | $3,763 | $2,829 |
| Hot Wells North Embayment | 0.10 | 8.39 | $6,225 | $742 | $287 | $2,870 |
| Conception Creek North Embayment | 0.12 | 8.51 | $6,584 | $774 | $359 | $2,992 |
| Mission Espada Embayment | 0.56 | 9.07 | $8,310 | $916 | $1,726 | $3,082 |
| Ashley Road Embayment | 0.51 | 9.58 | $9,892 | $1,033 | $1,582 | $3,102 |
| Berg's Mill Embayment | 0.29 | 9.87 | $10,802 | $1,094 | $910 | $3,138 |
| Hot Wells South Embayment | 0.74 | 10.61 | $13,127 | $1,237 | $2,325 | $3,142 |
| Ball Park Embayment | 0.32 | 10.93 | $14,157 | $1,295 | $1,030 | $3,219 |
| Brown Park Embayment (subset a) | 0.09 | 11.02 | $14,468 | $1,313 | $311 | $3,456 |
| Mission Espada Restored Remnant | 0.47 | 11.49 | $24,946 | $2,171 | $10,478 | $22,294 |
| San Juan Restored Remnant (subset b) | 0.76 | 12.25 | $52,069 | $4,251 | $27,123 | $35,688 |
| Conception Creek Trib Mouth | 0.11 | 12.36 | $105,828 | $8,562 | $53,759 | $488,718 |

**Figure 3-14**
**Graphical Incremental Cost and Output for Special Aquatic Measures**
**Design Condition 3B**




$488,718 versus an incremental output provided of 0.11 AAHU, was not carried forward to the final CE/ICA.

Table 3-35 displays all combinations of special aquatic features for each DC to be included in the final CE/ICA. Appendix E contains the CE/ICA input and output for the special aquatic features.

## FINAL COST EFFECTIVENESS AND INCREMENTAL COST ANALYSIS

For the final CE/ICA, channel configurations with associated incremental riparian vegetation measures, and special aquatic measure combinations were compared to answer the question, "*What combination of channel reconfiguration, woody riparian vegetation, and special aquatic measures provides the best incremental aquatic and riparian outputs for the cost*?"

For each design condition, plans were built incrementally and the AAC and AAHU for each were calculated. These plans and their associated costs and habitat output were input as fully formed plans in IWRPLAN. No plan was combinable with another. For each DC, the fully formed incremental plans were built in the following order:

1. Channel reconfiguration with riparian zone 1
2. Channel reconfiguration with riparian zone 1 and 2
3. Special Aquatic with channel reconfiguration and riparian zone 1
4. Special Aquatic with channel reconfiguration and riparian zone 1 and 2

**Table 3-35**
**Special Aquatic Combinations by Design Condition to be Carried Forward to the Final CE/ICA**

| Measure | Subsets | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DC1 | | | | | DC2 | | | | | | DC3A | | DC3B | |
| | A | B | C | D | E | A | B | C | D | E | F | A | B | A | B |
| *Wetlands* | | | | | | | | | | | | | | | | |
| Ashley Road | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| *Embayments* | | | | | | | | | | | | | | | | |
| Conception Creek | ♦ | ♦ | ♦ | ♦ | ♦ | | | | | | | | | | |
| Mission Road | ♦ | ♦ | ♦ | ♦ | ♦ | | | | | | | | | | |
| Hotwells | ♦ | ♦ | ♦ | ♦ | ♦ | | | | | | | | | | |
| Mission Espada | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Conception Park | | ♦ | ♦ | ♦ | ♦ | | | | | | | | | | |
| Brown Park | | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| E. Southcross | | | ♦ | ♦ | ♦ | | | ♦ | ♦ | ♦ | ♦ | | | | |
| E. White Ave | | | | ♦ | ♦ | | | | | | | | | | |
| Mission County Park | | | | | | | ♦ | ♦ | ♦ | ♦ | ♦ | | | | |
| Ball Park | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Golf Course | | | | | | | | | ♦ | ♦ | ♦ | | | | |
| Ashley Road | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Hotwells North | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Conception Creek South | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Hotwells South | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Berg's Mill | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Conception Creek North | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| *Tributary Mouths* | | | | | | | | | | | | | | | | |
| No Name | | | | | | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | | | | |
| San Juan | | | | | | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | | | | |
| Ashley Road | | | | | | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | | | | |
| Ball Park | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Hotwells | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Golf Course | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| Berg's Mill | | | | | | | | | | | | ♦ | ♦ | ♦ | ♦ |
| *Restored Remnants* | | | | | | | | | | | | | | | | |
| San Juan | | | | | ♦ | | | | | | ♦ | | ♦ | | ♦ |
| Mission Espada | | | | | | | | | | ♦ | ♦ | | ♦ | | ♦ |

There were 12 fully formed incremental plans for DC1, only one of which was cost-effective. There were no best buy plans in DC1. There were 14 fully formed incremental plans for DC2, of which nine were cost effective, and one plan was identified as a best buy. There were six fully formed incremental plans for DC3A, of which only one was cost effective, and identified as a best buy. There were also six fully formed plans for DC3B, of which only two were cost effective, and identified as best buy plans. Table 3-36 displays the input variables used in the final CE/ICA. An asterisk (*) denotes the plans identified as cost-effective. Table 3-37 summarizes the best buy plans, and Figure 3-15 provides a graphical representation of the best buys. A complete set of input and output tables for the CE/ICA analysis is found in Appendix E.

**Table 3-36**
**Fully Formed Incremental Plans and Inputs Used in the Final CE/ICA**

| Code | Design Condition | Channel Reconfigure | Riparian Zone | | Subset | | | | | | AAC | AAHU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | a | b | c | d | e | f | | |
| A1* | No action | | | | | | | | | | $0,000,000 | 54.5168 |
| B1 | 1 | ♦ | ♦ | | | | | | | | $2,610,411 | 122.2302 |
| B2 | 1 | ♦ | ♦ | ♦ | | | | | | | $2,652,727 | 139.2498 |
| B3 | 1 | ♦ | ♦ | | ♦ | | | | | | $2,601,383 | 128.7274 |
| B4 | 1 | ♦ | ♦ | | | ♦ | | | | | $2,605,052 | 128.3200 |
| B5 | 1 | ♦ | ♦ | | | | ♦ | | | | $2,611,478 | 128.2649 |
| B6 | 1 | ♦ | ♦ | | | | | ♦ | | | $2,622,526 | 128.3591 |
| B7 | 1 | ♦ | ♦ | | | | | | ♦ | | $2,648,882 | 128.4762 |
| B8* | 1 | ♦ | ♦ | ♦ | ♦ | | | | | | $2,709,144 | 146.0907 |
| B9 | 1 | ♦ | ♦ | ♦ | | ♦ | | | | | $2,712,813 | 145.6833 |
| B10 | 1 | ♦ | ♦ | ♦ | | | ♦ | | | | $2,719,239 | 145.7679 |
| B11 | 1 | ♦ | ♦ | ♦ | | | | ♦ | | | $2,730,287 | 145.8618 |
| B12 | 1 | ♦ | ♦ | ♦ | | | | | ♦ | | $2,756,642 | 145.9789 |
| C1* | 2 | ♦ | ♦ | | | | | | | | $2,383,267 | 113.6401 |
| C2* | 2 | ♦ | ♦ | ♦ | | | | | | | $2,447,910 | 139.5971 |
| C3* | 2 | ♦ | ♦ | | ♦ | | | | | | $2,387,657 | 116.8385 |
| C4* | 2 | ♦ | ♦ | | | ♦ | | | | | $2,388,375 | 116.8737 |
| C5 | 2 | ♦ | ♦ | | | | ♦ | | | | $2,389,564 | 116.8586 |
| C6 | 2 | ♦ | ♦ | | | | | ♦ | | | $2,390,140 | 116.8604 |
| C7* | 2 | ♦ | ♦ | | | | | | ♦ | | $2,399,976 | 116.9650 |
| C8* | 2 | ♦ | ♦ | | | | | | | ♦ | $2,426,332 | 117.0918 |
| C9* | 2 | ♦ | ♦ | ♦ | ♦ | | | | | | $2,452,300 | 142.7954 |
| C10* | 2 | ♦ | ♦ | ♦ | | ♦ | | | | | $2,453,019 | 142.8057 |
| C11 | 2 | ♦ | ♦ | ♦ | | | ♦ | | | | $2,454,207 | 142.7906 |
| C12 | 2 | ♦ | ♦ | ♦ | | | | ♦ | | | $2,454,784 | 142.7924 |
| C13 | 2 | ♦ | ♦ | ♦ | | | | | ♦ | | $2,464,619 | 142.8970 |
| C14* | 2 | ♦ | ♦ | ♦ | | | | | | ♦ | $2,490,975 | 143.0238 |
| D1 | 3a | ♦ | ♦ | | | | | | | | $3,433,652 | 120.2327 |
| D2 | 3a | ♦ | ♦ | ♦ | | | | | | | $4,252,011 | 172.0710 |
| D3 | 3a | ♦ | ♦ | | | | | | ♦ | | $3,415,772 | 127.6259 |
| D4 | 3a | ♦ | ♦ | | | | | | | ♦ | $3,445,240 | 128.1154 |
| D5 | 3a | ♦ | ♦ | ♦ | | | | | ♦ | | $4,234,130 | 180.5501 |
| D6* | 3a | ♦ | ♦ | ♦ | | | | | | ♦ | $4,263,598 | 181.0395 |
| E1 | 3b | ♦ | ♦ | | | | | | | | $3,285,381 | 121.8827 |
| E2 | 3b | ♦ | ♦ | ♦ | | | | | | | $4,159,460 | 172.3103 |
| E3 | 3b | ♦ | ♦ | | | | | | ♦ | | $3,265,232 | 129.3050 |
| E4 | 3b | ♦ | ♦ | | | | | | | ♦ | $3,293,320 | 129.7650 |
| E5* | 3b | ♦ | ♦ | ♦ | | | | | ♦ | | $4,139,324 | 180.5186 |
| E6* | 3b | ♦ | ♦ | ♦ | | | | | ♦ | ♦ | $4,167,412 | 180.9786 |

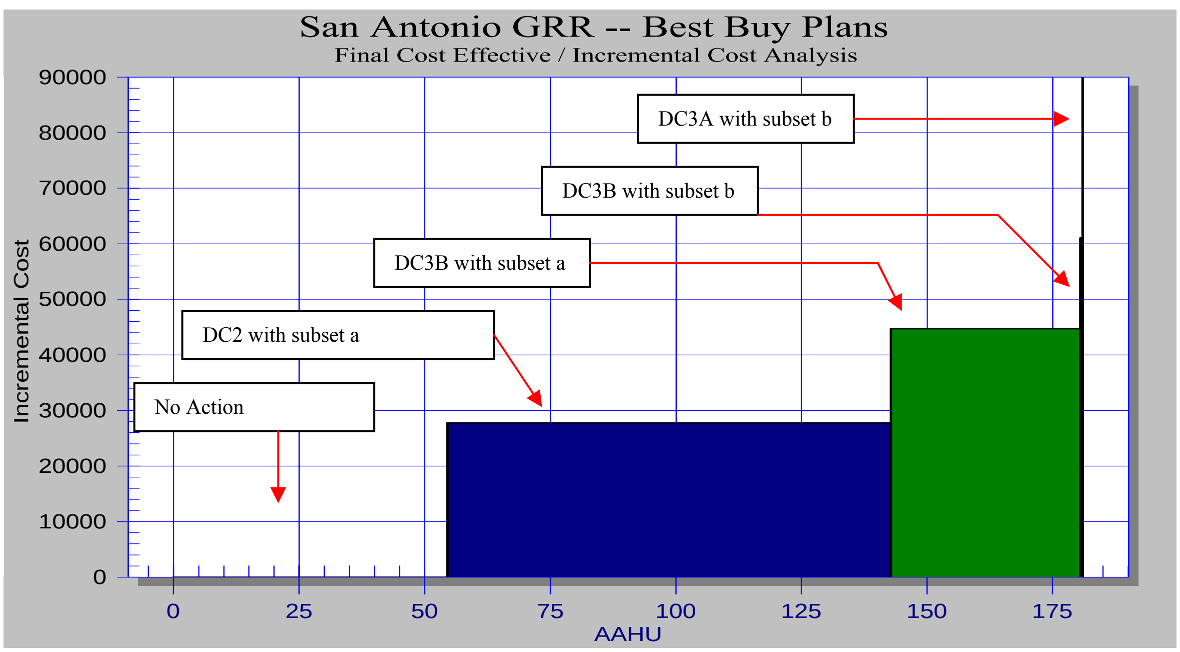
♦=Included in Plan *=Identified by IWR-PLAN as Cost Effective

**Table 3-37**
**Best Buy Plans (Potential NER Plans)**

| Code | Design Condition | AAHU | Incremental AAHU | AAC $ | Incremental AAC ($) | Incremental AAC per Output ($/AAHU) |
|---|---|---|---|---|---|---|
| A1 | Existing | 54.52 | 54.52 | 0,000,000 | 0,000,000 | 00,000 |
| C9 | DC2 | 142.80 | 88.28 | 2,452,299 | 2,452,299 | 27,779 |
| E5 | DC3B | 180.52 | 37.72 | 4,139,324 | 1,687,025 | 44,721 |
| E6 | DC3B | 180.98 | 0.46 | 4,167,411 | 28,087 | 61,058 |
| D6 | DC3A | 181.04 | 0.06 | 4,263,597 | 96,186 | 1,579,409 |

*Letter and number codes correspond to codes presented in Table 3-35

**Figure 3-15**
**Graphical Display of Best Buy Plans**



## IDENTIFYING THE NATIONAL ECOSYSTEM RESTORATION PLAN

The National Environmental Restoration (NER) plan will be selected from the best but plans listed in Table 3-37. The CE/ICA identified five best-buy plans in the final array. The five plans were evaluated with respect to the Corps ecosystem restoration mission, the study planning objectives, total habitat gains, incremental cost per incremental habitat unit gained, total project cost, level of support, and significance of habitat outputs. The following paragraphs provide justification for each incremental increase in cost associated with each incremental increase of output ultimately leading to the identification of the NER plan.

**No Action (Without Project)**. The no action plan was eliminated from consideration as the NER plan. Under the no-action plan, the aquatic and riparian habitats would remain in their current degraded condition. The no-action plan has an average annual output of 54.52 habitat units.

**DC2 with Subset A (DC2-A)**. The increment isolated by this plan over the without project condition is the pilot channel designed using the fluvial geomorphology design guidelines. DC2-A is comprised of an improved pilot channel (increased sinuosity, reduced gradient and velocity, improve sediment transport), special aquatic features, and riparian vegetation. DC2-A restores 434.59 acres of riverine ecosystem, and produces 142.80 AAHU. The 142.80 AAHU represents an increase of 88.23 AAHU over the without project condition. The incremental AAC per incremental AAHU is $27,779.

DC2 with subset A addresses most of the stated planning objectives, and represents a significant habitat improvement over the without project condition. Diversity of habitat is improved with the restoration of a one wetland, two embayments, and three tributary mouths. The riparian corridor further increases the habitat value of all aquatic measures. This best buy plan is within the Corps of Engineers authority to implement. It addresses the intent and spirit of the Corps ecosystem restoration mission, provides sustainable development, repairs past environmental damage, and works in conjunction with the existing flood control project.

**DC3B with Subset A (DC3B-A)**. The identification of DC2-A as a restoration plan in the interest of the Federal Government to implement, the question now becomes – "*is the next increment of restoration output (DC3B-A) in the interest of the Federal Government to implement?*" DC3B-A isolates the increment of real estate acquisition and additional excavation by this plan over DC2. The acquired real estate acquired is necessary to enlarge the floodway allowing for a more natural riparian corridor configuration, which in turn improves the aquatic habitat, increases the quality and quantity of embayments and tributary mouths, and to allow additional sinuosity to be returned to the San Antonio River.

DC3B-A restores 412.94 acres of riverine ecosystem, and produces 180.52 AAHU. The 180.52 AAHU represents a 126.0 and 37.72 increase over the without project and DC2A, respectively. The 37.72 AAHU gained has an average annual cost (AAC) per AAHU of $44,721 representing an incremental increase of $16,942 per AAHU gained over DC2-A.

There is reasonable justification for the Federal Government to participate in this additional increment, and identifying DC3B-A as the NER plan. First, DC3B-A produces output as a smaller average annual cost (incrementally between DC2-A and DC3B-A as compared to the without project condition and DC2-A). Further, the amount of riparian habitat acres are reduced from the 328.74 acres in DC2-A to 319.70 acres for DC3B-A (with a concurrent increase in AAHU of 30.63. Aquatic acreages increase 6.0, with a concurrent increase in AAHU of 6.33. The increases in aquatic outputs result from increase in the quantity of habitat and improvements to the quality of habitat. DC3B-A has four additional embayments provided over DC-A. The average SI for embayments in DC2-A is 0.60, while the average SI for embayments in DC3B is 0.87; an incremental improvement of 45% in habitat quality. One additional tributary mouth is gained with the implementation of DC3B-A. The quality of all tributary mouths is significantly increased over the quality provided by the riparian corridor of DC2. The average SI for tributary mouths in DC2-A is 0.48, while the average SI for tributary mouths in DC3B-A is 0.78. This represents an incremental increase of 62%.

The increases in the quality of restored aquatic habitats are solely attributed to the improvement in riparian habitat gained by enlarging the floodway to gain a greater capacity for riparian vegetation planting. D3B-A increases the acreage of Type A vegetation in riparian zone one from 11-acres in DC2 to 20 acres. This represents an 81% increase in the amount of Type A vegetation next to the water. Type C vegetation that occurs in zone one is increased from 19-acres to 32-acres in DC3B, a 68% increase, and Type D vegetation is increased from 29-acres to 64-acres, an 120% increase. Collectively, DC3B makes a 96% increase in the amount of woody vegetation occurring in zone 1 of the riparian corridor over that occurring in DC2. Increases in zone two vegetation for Types A, C, and D were equally significant over DC2, 250-, 173-, 56-percent, respectively. This means there was a decrease in grassland habitat from DC 2 of 71% in favor of restoring a more natural wooded riparian corridor in DC3B.

In addition to the improvements to aquatic habitat quality provided by the improved riparian zone of DC3B, the improvements to the riparian zone itself are significant. As previously discussed in the environmental significance section, riparian woodlands are critical components of wildlife habitat for numerous species of wildlife in San Antonio. Perhaps the most significant is the importance it plays for neotropical migrants as stop-over habitats, many of which depend on riparian habitats with a natural woody understory exclusively. Type A and C vegetation communities include some level of woody understory restoration. Type A understory will be allowed to develop naturally, and therefore, represents the best vegetation type, but Type C will be allowed to have some strips of naturally developing understory. Thirty percent (61 acres) of the riparian zone of DC2 is either Type A or Type C, while 45% (145 acres) of the riparian zone in DC3B is composed of the two best woodland vegetation types. Thus, DC3B provides a higher proportion of the most desirable vegetation types.

Another opportunity unique to the San Antonio River is the existence of National Park Service (NPS) lands adjacent to the project area. Because these lands occur adjacent to the project, there is an opportunity to provide connectivity and thus increase the benefits of the project outside the actual area of restoration work. Maximizing the amount of Type A or

Type C vegetation adjacent to these NPS lands is vital to providing a quality connection and increasing the value of both the NPS upland woodlands and the project's riparian woodlands. DC3B-A increases the amount of quality woodlands (Type A and C) adjacent to NPS lands by 4 times over that of DC2-A. Therefore, DC3B-A increases the quality and quantity of wildlife habitat by providing improved connectivity to the NPS wooded uplands adjacent to the project area.

This best buy plan is within the Corps of Engineers authority to implement. It addresses the intent and spirit of the Corps ecosystem restoration mission, provides sustainable development, repairs past environmental damage, prevents future environmental losses, and works in conjunction with the existing flood control project. Given the level and significance of output of output DC3B-A is within the Federal interest to implement.

**DC3B with Subset B (DC3B-B)**. The identification of DC3B-A as a restoration plan in the interest of the Federal Government to implement, the question now becomes – "*is the next increment of restoration output (DC3B-A) in the interest of the Federal Government to implement?"* DC3B-B contains the increment of restoring the two river remnants.

Restoring river remnants reestablishes the connectivity between the main channel and the old river meanders, a high ecological priority for all project participants. Several remnants of the San Antonio River, located outside the project footprint, were cut-off during channelization of the river for flood damage reduction. One of these remnants is connected to the river via an underground culvert preserving a historic (legal) water right. The other remnant is not connected to the river at the upstream end, and therefore it does not have a permanent source of water. Reconnection of this remnant to the main stem and reopening the channel for the other remnant provides important backwater and slack water habitats currently not available to the aquatic organisms of the river. The riparian vegetation and stream channel structure creating quality riverine habitat already exists in these old remnants; what is lacking is water and/or connection to the main stem of the river. The HSIs are 0.98 and 0.99 (at year 50), respectively, indicating high quality habitat. The subset of special aquatic measures included with this best buy provides for the reconnection of both remnants and the restoration of their upstream riparian corridor.

The incremental increase in output for this plan is the average annual habitat units gained from restoring connectivity of the two remnants to the main stem of the river and restoring their upstream riparian corridor. The increase in average annual habitat units is 0.46 with an average annual cost increase of $61,058 per average annual habitat unit, an incremental increase of $16,337 per habitat unit over the previous best buy plan. It should be noted that this incremental increase in cost is based upon the cost to gain an entire habitat unit, which is not possible and in-fact the actual incremental cost is only $7,515 to gain the reported 0.46 average annual habitat units. It is recognized these outputs come at a relatively high cost; however, from an incremental output and cost perspective, but the relative increase in incremental cost of the river remnants is driven by the relatively low cost of the embayments, tributary mouths, and wetlands. The cost of restoring river remnants represents less than one percent of the total first cost of all the measures combined.

Quality of the restored remnants was increased for DC3B over DC2, similar to the increase in habitat quality for embayments and tributary mouths seen by improving the vegetational community of the riparian zone. The average SI for restored remnants in DC3B was 0.98 compared to the average SI of 0.78 in DC2. This represents a 25% increase in habitat quality.

With respect to the above discussion, and DC3B-B is within the Corps of Engineers authority to implement. It addresses the intent and spirit of the Corps ecosystem restoration mission, fullfils all the study planning objectives, provides sustainable development, repairs past environmental damage, prevents future environmental losses, and works in conjunction with the existing flood control project. Therefore DC3B-B is in the Federal interest to implement.

**DC3A with Subset B (DC3A-B)**. This best buy plan (the last increment) incorporates many all of the same aquatic features as Best Buy Plan #4; however, the vegetation plan is different and there is only 1 riffle located in the entire eight mile restoration area. More importantly, the previous best buy plans provide outputs at much lower costs. There is no overriding justification for a Federal interest in implementing DC3A-B. Therefore, it will not be considered as a NER Plan.

**National Ecosystem Restoration Plan**. Based upon the analysis described above, DC3B-B has been identified as the NER Plan. DC3B-B provides a comprehensive and balanced restoration of lost riverine environments than any other plan evaluated during plan formulation. The cost of implementing this plan is justified based upon the significant outputs it provides to the riverine environment, particularly aquatic, of the San Antonio River. These outputs include significant increases in the quality and quantity of scarce aquatic and riparian habitats in the project area, and are technically and institutionally significant. Restoration of these habitats is considered of great ecological importance to the city of San Antonio, Bexar County, and the San Antonio River Authority, the state of Texas and the nation. Further, DC3B -

- Results in greatest improvement in sinuosity, slope gradient, velocity and sediment transport
- Restores the river to a more natural configuration and function
- Restoration to pre-SACIP conditions not practical from a financial perspective; DC3B-B reasonably maximizes aquatic and riparian habitat
- Captures the synergy between riparian and aquatic habitats
- Provides greatest diversity in aquatic and riparian habitats
- Restores scarce habitats, particularly river remnants
- Restores significant resources (see Chapter 4 - Recommended Plan for complete discussion on significance)
- The estimated total first cost of restoring two river remnants is less than one-half of one percent of the estimated total project first cost.
- DC3B-B is an opportunity to demonstrate progressive commitment to the principles of environmental restoration by the Corps of Engineers.